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GARUSO: Stakeholder Participation Beyond Organizational Limits

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by
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The Faculty of Economics, Business Administration and Information Technology of the University of Zurich herewith permits the publication of the aforementioned dissertation without expressing any opinion on the views contained therein.

Zurich, October 24, 2018

Head of the Ph.D. committee for informatics: Prof. Dr. Thomas Fritz

Imagination is the Discovering Faculty, pre-eminently.
It is that which penetrates into the unseen worlds around us,
the worlds of Science.

Ada Lovelace, First Computer Programmer, 1815 – 1852

The arts and sciences are avatars of human creativity.

Mae Jemison, First African-American Female Astronaut, 1956-present

Play is the highest form of research.

Albert Einstein, Physicist, 1879 - 1955

Acknowledgement

Certainly, travel is more than the seeing of sights; it is a change that goes on, deep and permanent, in the ideas of living.

Miriam Beard, Historian, 1876 – 1958

This is the day. After an intense time of traveling, writing these feelings of gratitude adds the finishing touch to my thesis. I have always sought and enjoyed discovering the unknown, learning from it and sharing the experiences. Yet, this would not have been possible by my own. I am deeply grateful to all the people who have supported me creating my path during this time of travel.

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Martina Kolpondinos, Zurich, July 2018

Abstract

Stakeholder participation is a cornerstone of effective Requirements Engineering (RE). It supports the development and evolution of software systems so that they fit their intended purpose within their application domain. To enable successful stakeholder participation RE experts have created a broad variety of approaches for different circumstances and project phases. These approaches focus on traditionally dedicated software systems, which have closed and location-bound user groups. The stakeholders of these systems usually are members of the organizations that commission or build the system. Meanwhile, technological development has opened doors for ubiquitously deployed and openly available software systems. Stakeholders of these systems are rarely members of those organizations. Instead, they are so-called *outside organizational reach* and typically unknown to RE experts. Hence, in contrast to stakeholders of traditionally dedicated software systems, they can neither straightforwardly be identified nor be requested to participate in RE. Moreover, they are likely location-independent, numerous and highly heterogeneous. Current RE approaches do not suffice to address these challenges.

Established RE approaches provide limited means to identify stakeholders outside organizational reach, let alone motivate them to voluntarily participate in RE. They also cannot support collaboration in distributed settings or on a large scale, yet, collaboration is known to be essential for the development of novel systems and in unknown domains. Feedback mechanisms and social network sites enable distributed and large-scale collaboration. However, their effectiveness is limited as they originally have no RE purpose and typically are restricted to their members. Latest RE approaches close this gap and also apply motivation strategies, which, however, are simplified, missing the high heterogeneity of stakeholders outside organizational reach; thus, risking to demotivate them.

This thesis presents the GARUSO (**G**ame-b**a**sed **R**eq**u**irement**s** Elicitati**o**n) approach, a novel RE approach specifically designed for stakeholders outside organizational reach. It provides (1) a strategy to identify them and (2) a social media based platform that enables their collaborative participation in RE and applies gamification to motivate them to do so.

The GARUSO platform is the core of the thesis. Its conceptual solution is inspired by the structure of user stories, the experiential learning theory, motivational psychology and game design. As a proof of concept, it was implemented to elicit and prioritize requirements and evaluated in a field study with promising results: The identified stakeholders build a highly heterogeneous crowd which participated - over a period of three months - in platform activities. They perceived the platform easy to understand, interesting to use and during their participation increased their knowledge on the application domain of the software system of interest.

Zusammenfassung

Stakeholderbeteiligung ist ein Eckpfeiler des effektiven Requirements Engineering (RE). Sie unterstützt die (Weiter-) Entwicklung von Softwaresystemen, sodass diese ihren Anwendungszweck erfüllen. Um eine erfolgreiche Stakeholderbeteiligung zu ermöglichen, haben RE-Experten eine Vielzahl von Ansätzen entwickelt. Diese fokussieren auf traditionell dedizierte Softwaresysteme mit geschlossenen und standortgebundenen Anwendergruppen. Die Stakeholder dieser Systeme sind üblicherweise innerhalb der Organisationen, die am Systemauftrag oder der Systemerstellung beteiligt sind. Unterdessen haben technologische Entwicklungen Türen für allgegenwärtige und frei verfügbare Softwaresysteme geöffnet. Deren Stakeholder sind selten innerhalb der erwähnten Organisationen. Stattdessen sind sie *Stakeholder ausserhalb organisatorischer Reichweite*, den RE-Experten meistens unbekannt, standortunabhängig, zahlreich und sehr heterogen. Aktuelle RE-Ansätze reichen hier nicht aus. Etablierte RE-Ansätze bieten beschränkt Möglichkeiten um diese Stakeholder zu identifizieren, geschweige denn zu motivieren. Zudem unterstützen sie weder eine ortsunabhängige und somit verteilte Zusammenarbeit noch deren Skalierbarkeit.

Zusammenarbeit ist jedoch wichtig für die Entwicklung neuartiger Systeme und in unbekannten Domänen. Feedback-Mechanismen und Social Network Sites helfen hier. Sie eignen sich aber nur bedingt für RE und beschränken den Zugang meist auf ihre Mitglieder. Neueste RE-Ansätze schliessen diese Lücke. Zudem wenden sie Motivationstechniken an, die jedoch vereinfacht sind und so die hohe Heterogenität der Stakeholder ausserhalb organisatorischer Reichweite vernachlässigen, was diese demotivieren kann.

Diese Dissertation stellt den GARUSO (**G**ame-b**a**sed **R**eq**u**irement**s** Elicitati**o**n) Ansatz vor, einen neuen RE-Ansatz, der speziell für Stakeholder ausserhalb organisatorischer Reichweite entwickelt wurde. Er bietet (1) eine Identifizierungsstrategie für diese Stakeholder und (2) eine auf sozialen Medien basierende Plattform, welche die verteilte Zusammenarbeit ermöglicht, skaliert und Gamification anwendet, um Stakeholder zur Teilnahme zu motivieren.

Die GARUSO-Plattform ist der Kern der Dissertation. Ihre konzeptionelle Lösung ist durch die Struktur von User Stories, dem erfahrungsbasierten Lernen, der Motivationspsychologie und dem Spieldesign inspiriert. Als Machbarkeitsnachweis wurde sie zur Anforderungserhebung und -priorisierung implementiert und anschliessend in einer Feldstudie mit vielversprechenden Ergebnissen evaluiert: Die identifizierten Stakeholder bilden eine sehr heterogene Gruppe, welche - über einen Zeitraum von drei Monaten - an den Plattformaktivitäten teilnahm. Die Teilnehmenden empfanden die Platform als leicht verständlich und interessant und viele berichteten, dass sie ihr Wissen über den Anwendungsbereich des Softwaresystems, für welches die Anforderungen erhoben und priorisiert wurden, durch ihre Teilnahme erweitern konnten.

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1.1 Introduction

Successful software systems satisfy both social and technical requirements [Gog94]. They should also consider requirements that support sustainable development [LP17]. Meeting these conditions is a complex challenge, since requirements must be not just collected but elicited instead [ZC05]. In requirements engineering (RE), this process is known as requirements elicitation and described as "seeking, uncovering, acquiring, and elaborating requirements" of software systems [ZC05, pp. 19] from different sources [Gli11]. Among the most important sources are the stakeholders of a software system. Stakeholders are individuals or organizations who influence the requirements of a software system or are influenced by the system itself [GW07].

New classes of software systems have evolved over the past years. Among them, in particular, the ubiquitously deployed and openly available ones have changed important stakeholder characteristics. The majority of stakeholders of these systems is not a member of the organizations which order or supply the system nor of any well-known related organization. These stakeholders are so-called *outside* organizational reach. Typically, they are unknown to the driving forces behind RE projects, location independent, highly heterogeneous, and numerous.

A wide spectrum of techniques exists to elicit requirements under various circumstances for specific purposes and from different stakeholder groups [ZC05]. They were designed under the assumption that stakeholders can straightforwardly be identified, requested or even mandated to participate in RE and instructed on how to do so. However, neither of these assumptions holds for stakeholders outside organizational reach. Moreover, established RE techniques do not scale with respect to collaboration. Feedback mechanisms and SNSs can facilitate large-scale collaboration in RE. They are, however, limited with regard to RE activities and restricted to system users and network members, respectively.

The lack of means to involve stakeholders outside organizational reach in RE threatens the success of software systems. This is especially the case for ubiquitously deployed and openly available software systems as these systems have disruptive potentials. In fact, these systems typically drive people's consumption patterns and enable them to access specific information [BCD+15], making it possible to instantly "share" skills, spaces, goods or time with anyone for monetary or non-monetary incentives.

These peer-to-peer based activities are often referred to as *sharing economy* [BR11]. Established economic systems and markets like tax markets and labor markets are challenged by the sharing economy as it blurs the boundaries between product providers and product consumers [Sel17]. In addition, ubiquitous software systems enable the acquisition of personal information, which is likely to also influence people's decisions. For example, fitness trackers monitor health indicators such as heart rates and performed activities often used for the quantified self [Wol12]. Smart meters measure the domestic energy consumption [MCG99] and provide real-time information to customers when connected to an in-house display. Moreover, the Internet of Things [Wei91] follows the idea to interconnect different physical devices such as fridges, heating systems and weather sensors within and across societies.

Technological development is likely to increase the numbers of stakeholders outside organizational reach. At the same time, the growing influence of software systems in and on people's lives impacts the environmental, social, and economic context [BCD+15]. Research warns that the incapability to involve stakeholders of these systems in RE will significantly challenge those contexts.

In fact, producing and running a software system demands for natural resources and disposing it produces waste. This causes immediate or so-called *direct effects* of the software system. Moreover, as previously outlined, utilizing a software system influences how people act and decide and as such causes so-called *indirect effects* of the software system. Typically, direct effects are deemed to mostly affect the environmental context [KHG+17] and indirect effects to have a major impact in all three contexts [HA15].

In summary, stakeholder participation in RE activities is essential for the success of a software system [NE00, GW07, ZDS$^+$09, KSK14] and to forecast potential effects of the system [BBC$^+$16]. Current RE approaches can, however, not sufficiently support the participation of stakeholders outside organizational reach in RE activities. Yet, the number of these stakeholders is increasing. As a consequence, we face a serious *stakeholder participation problem* that is defined by three major shortcomings:

1. The limitation to identify stakeholders outside organizational reach;
2. The lack of concepts to motivate them to participate;
3. The inability to enable stakeholder collaboration in distributed settings and on a large-scale.

The current state of the art, therefore, needs to be extended with approaches that address these points.

1.2 Background and State of the Art

This section presents the background and approaches that are relevant when considering the participation of stakeholders outside organizational reach in RE, clarifying the terms *user involvement* and *user participation*, and showing how they relate to system success. Moreover, this section will highlight the three aforementioned challenges faced by RE experts:

Thereby, it (a) addresses issues related to *stakeholder identification*; (b) describes the *conceptual gap* that limits the potential to motivate stakeholders outside organizational reach to participate in RE activities; (c) shows the *technological gap* that challenges the collaboration of stakeholders outside organizational reach in RE with respect to distributed settings and large scales.

1.2.1 User Involvement and its Influence on the Success of a Software System

Intuitively user involvement in system development significantly contributes to the success of the system [OI81]. For example, in RE, research results strongly indicate that overlooking stakeholders provides incomplete requirements [AR04], leads to wrong software products [LQF10a] and might kill the project [GW07]. Stakeholders who are ignored tend to shift to alternative products or harm the reputation of the developing software company [MP11]. Research results also suggest that early user involvement leads to more accurate requirements [Kuj03] and reduces the necessity to involve users in later phases of software development [BZ15].

The term *involvement* is, however, often used vaguely in software development [BH89, BZ15] and its relation to system success is not always straightforward [MM04]. It is, for example, unclear how "user involvement" relates to "user participation". Kujala [Kuj03] found that "user involvement" is often used to loosely explain any direct contact with users. For example, Olson & Ives [OI81] consider "user involvement" a synonym for "user participation".

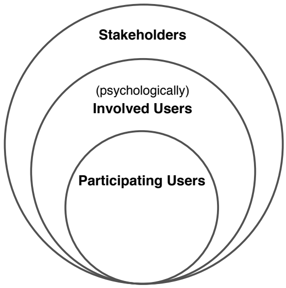

Figure 1.1: The relation between stakeholders, involved users, and participating users, adapted after [BH89, BZ15]

In contrast, Barki & Hartwick [BH89] suggest that "user involvement" and "user participation" focus on psychological experiences and performed activities, respectively. They describe "user involvement" as a *"subjective psychological state reflecting the importance and personal relevance of a system"* (p. 53) and "user participation" as *behaviors and activities during the development process.*

Based on this distinction between "user involvement" and "user participation", the traditional information system participation theory suggests that: the users' psychological involvement is the link between their participation in the development process and the success of a software system [MM04].

Similarly, in RE, Bano & Zowghi [BZ15] define users who participate as a subset of users who are involved, who in turn are a subset of stakeholders (see Figure 1.1). They investigated the influence of user involvement on system success in software development with a systematic review of 87 studies. The findings of their study provide evidence for such an influence.

The results, particularly, reveal that users are more satisfied with utilizing a software system if they perceive they have had control over the development process. Bano & Zowghi [BZ15], therefore, suggest that enabling users to participate, i.e., involving them, in software development, influences system success even if the involved users do not participate [BZ15].

1.2.2 The Identification of Stakeholders Outside Organizational Reach

Stakeholders of traditionally dedicated software systems with closed and location-bound user groups are typically *within* organizational reach. This means they are members of the organizations that commission or build the system. These stakeholders are usually known to RE experts. Their identification is, therefore, considered to be rather straightforward.

Over the last years, software systems have shifted from traditionally dedicated systems to ubiquitously deployed and openly available ones that are embedded in real-life contexts. In contrast to stakeholders of the former systems who were within organizational reach the ones of the latter are, typically, outside organizational reach. This means, they are not members of the organizations that commission or build the system nor of any well-known related organization. Hence, their identification is more complex compared to the one of stakeholders within organizational reach. Current RE approaches cannot sufficiently support their identification.

The distribution of questionnaires and announcement of polls are two examples of established RE approaches that could support the identification of stakeholders outside organizational reach. It should, however, be stated that both approaches lack a strategy to effectively do so. With focus on such a strategy, this thesis identifies the *snowballing process*, one of the most cited stakeholder identification strategies in RE. The snowballing process is recursive and was originally used in mathematical statistics to identify individuals of a population by already identified individuals [Goo61].

In RE, Lim et al. [LQF10a] adapted the snowballing process to identify and prioritize stakeholders of large-scale software projects [LDIF13]. They achieved promising results. However, their approach is not sufficient with respect to stakeholders outside organizational reach. On one side, it assumes that initial key stakeholders are known [LQF10a], which is not necessarily the case for stakeholders outside organizational reach. On the other side, it requires that stakeholders know each other. Stakeholders outside organizational reach are, however, likely members of different online communities and research shows that the identification of online community members across communities is limited [Har07].

The field of Crowdsourcing also aims to attract a large number of people. Here, the people of interest are location-independent and willing to solve microtasks over online platforms. Typically, monetary incentives are used to motivate them to participate in these tasks, e.g., in Amazon Mechanical Turk[1]. The large number of participants on these platforms seems to confirm the success of this approach.

[1] https://www.mturk.com

However, it is commonly acknowledged that monetary incentives can undermine people's previously inherent motivation [RD00]. They, therefore, bear a high risk of flawed contributions.

To limit the risk of flawed contributions in crowd-sourcing due to monetary incentives and to provide a more price effective solution Ipeirotis & Gabrilovich [IG14] followed a different approach. They used the online advertisement network Google Adwords[2] to attract people to their online platform for the purpose of collecting knowledge.

In contrast to the previously referenced snowballing process their approach addresses the challenge of not knowing the participants and does not depend on participants knowing each other. However, it only focuses on one online channel, which limits stakeholder identification across communities. Moreover, it provides no means with regard to motivation. How to motivate stakeholders outside organizational reach to participate in RE activities is, however, a major concern in RE. For example, Bano & Zowghi [BZ15] identified the lack of motivation to participate in software projects as the main challenge for effective stakeholder involvement.

1.2.3 The Role of Gamification in Requirements Elicitation

RE experts recently started to apply the concept of *Gamification* to address the challenge of motivating stakeholders to participate in RE activities.

[2] https://adwords.google.com/

Gamification is a concept that describes the use of game elements, as, for example, points, levels or badges, in a non-game context [DDKN11][3]. The goal of applying gamification is to harness the motivational power of games to drive people towards solving real-world problems [LH11]. Motivation is, thereby, considered a continuum of fluctuating intensity as defined by Ryan & Deci [RD00]. Hence, gamification is applied to *maintain* or even *increase* people's motivation with respect to an intended purpose. To satisfy this purpose, two conditions must be met.

Firstly, the people to be motivated need to have an interest in the product or service to or for which gamification is applied [Det12]. Stakeholders of a software system meet this condition as they by definition have an interest in the system (see [GW07]). Secondly, the gamification concept needs to be carefully designed. Equal considerations like the ones for monetary incentives previously stated in this thesis should be given to gamification because gamification can undermine people's inherent motivation for participation too. This typically occurs when game elements are randomly applied or the rewards have no value to users. Kankanhalli et al. [KTCK12] found, for example, that gamification usually fails to motivate users if it is not tailored to their personality or if it does not consider the application domain. Similarly, Richter et al. [RRR15] highlight that whether people perceive strategies as motivating depends on their values and goals.

[3] The original definition by Deterding reads as follows: “Gamification is the use (rather than the extension) of design (rather than game-based technology or other game-related practices) elements (rather than full-fledged games) characteristic for games (rather than play or playfulness) in non-game contexts (regardless of specific usage intentions, contexts, or media of implementation).”

In RE, initial gamification approaches show encouraging results in motivating stakeholders within organizational reach to participate in RE activities. For example, Fernandes et al. [FDR+12] yield very satisfying numbers of high quality requirements that were generated with the Web-based gamification environment iThink. Snijders et al. [SDB+15] show positive influences of gamification on the collaborative elicitation and prioritization of requirements by the users of their online platform REfine. Furthermore, Lombriser & Dalpiaz [LDLB16] obtained requirements of higher number, quality and creativity by the users of their elicitation platform when gamification was applied.

The underlying motivational concepts of current gamification approaches applied in RE are, however, not sufficient with respect to stakeholders outside organizational reach. In fact, these concepts assume that stakeholders are equally motivated to participate in RE activities and that they share the same level of experience on how to participate.

For example, iThink [FDR+12] and REFine [SDB+15] both emphasize gathering points and normative comparisons and thus focus on a competitive motivation strategy. Most recently, Lombriser & Dalpiaz [LDLB16] applied a more diverse motivation strategy, which, however, uses an out-of-the-box gamification API. Hence, their approach either assumes that stakeholders are familiar with the API and experienced in the application domain, or that they can be instructed by RE experts additionally. Especially the latter is rarely the case for stakeholders outside organizational reach.

In summary, the current gamification approaches applied in RE use motivation concepts that are limited with respect to the high heterogeneity of stakeholders outside organizational reach. Here, *high* refers to the number of variables that add to people's heterogeneity as for example their demography, experience, role, culture and education.

The current limitations of gamification concepts that are applied in RE represent a *conceptual gap*, which limits the effectiveness of existing concepts to motivate stakeholders outside organizational reach with diversified means to participate in RE activities.

1.2.4 Collaborative Requirements Elicitation in Distributed Large-Scale Settings

Collaborative RE techniques have a high potential to support RE activities. Mahaux et al. [MNG$^+$13] emphasize, for example, that collaboration among stakeholders is essential to solve conflicts between them. Konaté [KSK14] considers collaboration in RE necessary to facilitate the elicitation of rich, complete and consistent software requirements.

Arias et al. [AEF$^+$00] highlight the importance of stakeholder collaboration to benefit from knowledge that is shared among stakeholders. Furthermore, Geisser & Hildebrand [GH06] emphasize the high value of collaboration to understand customers' needs.

In distributed settings, stakeholder collaboration moreover enhances the benefits of co-located collaboration. For example, Damian [Dam07] emphasizes that distributed collaboration enables RE experts to understand requirements with respect to human aspects like social roles and cultures.

With focus on stakeholders outside organizational reach distributed collaboration might even trigger *the wisdom of the crowd* [Sur04]. This phenomenon describes that under certain conditions a group of people is smarter collectively than any of the smartest individuals within the group. Thereby, the group members are neither required to be well-informed nor to be rational. They do, however, need to be diverse, have independent opinions and be decentralized - in the sense that they draw from their own knowledge -. Stakeholders outside organizational reach are likely to meet these conditions.

Stakeholder collaboration might also be indispensable with respect to ubiquitously deployed and openly available software systems. These systems are highly interwoven with various parts of peoples' lives. Their utilization is therefore more likely to cause effects that are uncertain compared to the ones caused by the utilization of traditionally dedicated software systems.

Sutcliffe & Sawyer [SS13] highlight the necessity of collaboration in such "green-field" domains, i.e. domains in which few solutions exist and experience is low, due to its inherent potential of developing creative solutions. Similarly, Potts [Pot95] emphasizes that requirements for "off-the-shelf" software systems cannot just be collected but rather emerge as a result of collaboration.

Despite the advantages and the need for stakeholder collaboration only a few RE approaches facilitate large-scale collaboration among stakeholders. For example, WikiWinWin [YWK+08], a Wiki-based system facilitates the collaborative negotiation of requirements. Athena [LBB09], a Web-based tool fosters the collaborative refinement of requirements from vague descriptions to specific use cases. These approaches are, however, designed for stakeholders within organizational reach.

With focus on stakeholders outside organizational reach, feedback mechanisms are typically used to facilitate collaboration among the end-users of a software system. For example, app stores can provide a means to rate and comment on apps, and to rate the comments [PM13]. In-app feedback was, furthermore, identified as the most influential feedback mechanism for software products with more than 5'000 end-users [Use].

Most recently, stand-alone feedback applications have been developed. For example, FAME [OHSF+18] a stand-alone feedback app for mobile devices enables its users to provide and evaluate feedback on other software products.

Similarly, in industry, the company UserVoice[4] offers a stand-alone service that enables companies to capture feedback about their software products from location independent stakeholders. Furthermore, open source projects enable their members, e.g., end-users, developers or domain experts to report and discuss bugs and features of different versions of a software product [JM15].

[4] https://www.uservoice.com/

However, feedback mechanisms focus on the evolution of a software system. This limits their effectiveness with respect to software development and as such in anticipating the disruptive potential of ubiquitously deployed and openly available software systems. In addition, in-app approaches are restricted to the app users.

SNSs are also increasingly used by RE experts as a means for collaborative stakeholder participation. For example, the microblogging platform Twitter is used to discuss pros and cons of software systems [GAS17]. On Facebook, RE experts can create topic-specific groups to manage such discussions [STC$^+$15]. These approaches support both system development and evolution, but they are limited with respect to stakeholders outside organizational reach as they are restricted to the SNS members.

Altogether, the current state of the art of RE approaches represents a *technology gap* with respect to distributed and large-scale collaboration, which hinders stakeholders outside organizational reach to effectively participate in RE activities.

1.3 RE in the Context of Sustainable Development

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [WD87, p.41].

The underlying challenge in sustainable development is that to satisfy a human need, natural resources are required and effects caused, which both can interfere in the satisfaction of any other human need. Software systems, particularly ubiquitously available ones, are expected to increase this challenge. Therefore, investigating software systems with a focus on sustainable development is an increasing necessity [SHK09, HA15].

This section elaborates on the role of RE with respect to the growing impact of software systems on sustainable development. It also describes the different effects that are caused by the application of software systems and how they influence the transition towards sustainable development. Finally, it will show how these effects are analyzed in the broader context of RE and explain the role of stakeholder involvement in the anticipation of these effects.

1.3.1 Background

Sustainable development is a global concept, which considers *intragenerational* and *intergenerational* justice as it aims to enable people to satisfy their needs regardless of time and space [SHK09]. Effects caused by satisfying human needs can challenge the transition towards sustainable development. Traditionally, these effects are evaluated with respect to the environmental, societal and economic contexts, and sustainable development addressed by balancing these effects between the three contexts. However, by definition, the economic system is part of society, which in turn is part of the environment (see Figure 1.2).

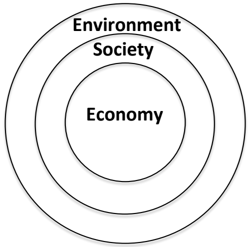

Figure 1.2: The nested sustainability aspects, adapted after [HA15]

This implies that finding a balance between the three contexts is impossible as there is no balance between a whole and its part [HA15]. The definition of sustainable development also implies that no single technology can be sustainable by itself. However, the technology design has an influence on whether the effects that are caused during the life cycle of that technology hinder the transition towards sustainable development or (presumably) support it [HA15, BCD+15].

Figure 1.3 illustrates the life cycle of a software system with the three life cycle phases production, utilization and disposal, and the two classes of effects that are caused during these phases.

The effects that are caused by the demand for natural resources during the life cycle of a software system are so-called *direct effects* (1). Natural resources such as energy and materials are demanded by the hardware, which in turn is demanded by the software [KHG+17]. This implies that the software design highly influences the demand for natural resources and as such the direct effects of the software system.

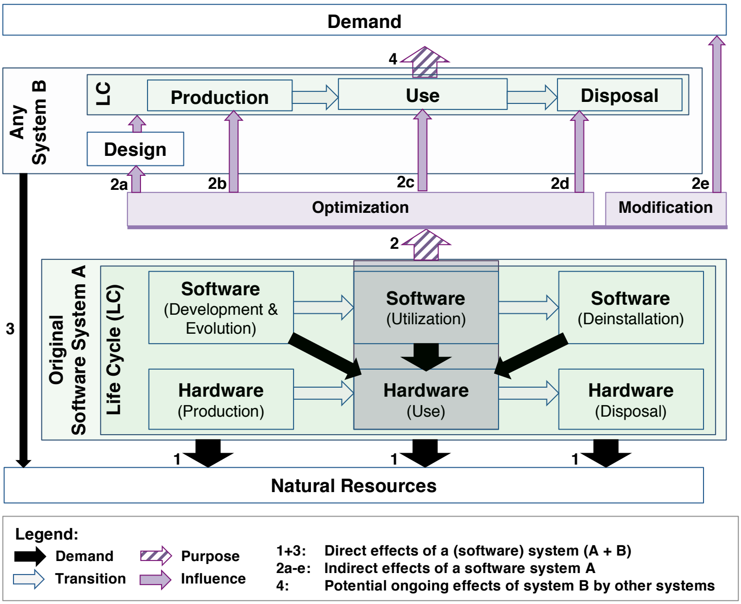

Figure 1.3: The life-cycle of a software system with direct effects (1), potential indirect effects (2a-2e), and effects of affected systems (3), (4), adapted after [KHG+17, HLH11]

The software design also plays a major role with respect to *indirect effects* of a software system, which are caused by the utilization of that system. Typically, software systems are utilized to optimize or modify the life cycle of other systems (2). Thereby, they can indirectly change people's consumption behavior (2e; 4) and affect the direct effects that are caused by those other systems (3). Over time, indirect effects, therefore, can also influence economic structures and institutions. Both direct and indirect effects are explained in more details in the next sub-section.

1.3.2 Effects of Software Systems

Direct effects of a system are immediately caused during the life-cycle of that system. Traditionally, direct effects are considered in the environmental context and as such focus on the demand for natural resources [BH01]. From this viewpoint, direct effects can exclusively hinder the transition towards sustainable development [BH01] as they represent the costs of applying a software system [HA15]. Most recently, RE researchers have started to investigate direct effects of software systems while considering societal and economic aspects such as working conditions and salaries [NDKJ11]. From this viewpoint, direct effects can also support the transition towards sustainable development.

Indirect effects are caused by the utilization of a system and traditionally considered within all three contexts: environmental, societal and economic. They refer to how human activities are changed and reorganized [BH01] and include long-term impacts on lifestyles and institutions [HA15]. With respect to a software system, indirect effects are influenced by the design (2a) and caused by the life cycle phases (2b-2d) of any system - including non-software systems - that is affected by utilizing the software system (see Figure 1.3). They also consider future demands (2e) that are (potentially) caused by its utilization, including substitution (e.g., if video conferences substitute physical travel) and induction (e.g., if a navigation system induces transport demand) [HA15]. Indirect effects can support (e.g., re-use) or hinder (e.g., consumerism) the transition towards sustainable development. Compared to direct effects they are, however, typically uncertain [BH01].

1.3.3 Practices to Analyze Effects of Software Systems in RE

To support analyzing effects of software systems in the broader context of RE a group of researchers created The Karlskrona Manifesto for Sustainability Design (KMSD) [BCD$^+$15]. The KMSD is a living set of principles and commitments [5].

For the purpose of analysis the KMSD uses five interdependent sustainability dimensions that include the three traditional contexts (economy, society, environment) and complements them with the individual (or human) context introduced by Goodland [Goo02] and the technical context suggested by Penzenstadler & Femmer [PF13].

This thesis has classified four research directions that are considered most relevant to the thesis scope with respect to the dimensions used by the KMSD. Figure 1.4 shows the classification of the research directions with information added to indicate their focus with respect to direct effects (DE) and indirect effects (IE). All four research directions satisfy the definition of *Sustainable Software Engineering* as "the art of defining and developing software products in a way so that the negative and positive impacts on sustainability that result and/or are expected to result from the software product over its whole life-cycle are continuously assessed, documented, and optimized." by Dick & Naumann [DN10, p. 708]. Subsequently, the research directions are described in more detail.

[5] The current version of the manifesto is accessible online: http://sustainabilitydesign.org

Sustainability Dimensions [BCD+15]		**Research Directions** [1]			
		SE			**RE**
Name	**Description**	**S for SE** [Pen13]	**S in SE** [Pen13]	**SE for S** [PRR+14]	**RE4SuSy** [PMS13]
Environmental [UN187]	Concerns long-term effects of human activities on natural systems, e.g., food production, water consumption, pollution, waste disposal.	**DE**	**DE**	**DE&IE**	**DE&IE**
Economic [UN187]	Focuses on financial capital and added values, e.g., the creation of wealth and prosperity.	**DE**	**DE**	**DE&IE**	**DE&IE**
Social [UN187]	Refers to structures that support the protection of vulnerable groups in society, e.g., social equity, justice, employment, democracy.			**DE&IE**	**DE&IE**
Individual [Goo02]	Concerns the well-being of humans as individuals, e.g., mental and physical well-being, education, mobility.	**DE**		**DE&IE**	**DE&IE**
Technical [PF13]	Focuses on measures that support the longevity of information, systems, and infrastructure and their adequate evolution under changing conditions, e.g., maintenance, innovation, obsolescence, data integrity.		**DE**	**DE&IE**	**DE&IE**

[1] satisfying the definition of Sustainable Software Engineering [DN10]

Legend: DE: Direct Effects IE: Indirect Effect S: Sustainability SE: Software Engineering RE: Requirements Engineering

Figure 1.4: The four research directions on sustainable development that are most relevant to this thesis, classified according to the sustainability dimensions by the KMSD [BCD+15] and with respect to the directions' focus on direct and indirect effects.

Sustainability for Software Engineering (S for SE) [Pen13] investigates how *SE practices* can support the transition towards sustainable development. It targets effects of software development and maintenance, which includes environmental and financial impacts, and working conditions. Hence, *S for SE* addresses direct effects in the environmental, economic and individual dimension.

Sustainability in Software Engineering (S in SE) [Pen13] looks at how *software systems* can support the transition towards sustainable development. It focuses on effects caused by a system itself due to the production and utilization of the system. This includes effects caused by the demand for resources needed to run the system and the system lifetime. Hence, *S in SE* focuses on direct effects in the environmental, economic, and technical dimension.

Software Engineering for Sustainability (SE4S) [PRR$^+$14] combines the focus of *S for SE* and *S in SE*. It also considers effects that are induced by the utilization of a software system but not directly caused by the system itself. Thus, *SE4S* addresses direct and indirect effects of a software system with respect to all five sustainability dimensions.

RE for Sustainable Systems (RE4SuSy) [PMS13] regards RE as a key success factor in the context later defined by *SE4S*. Thereby, *RE4SuSy* focuses on how RE activities can support both reducing effects of software systems that are considered unfavorable and increasing the ones that are deemed to be favorable. Thus, *RE4SuSy* address direct and indirect effects with respect to all sustainability dimensions from an RE perspective.

In addition to the five sustainability dimensions, the KMSD introduces three scopes of concerns that relate to the nature of software systems: techno-centric scope (e.g., system quality), eco-centric scope (i.e., how the system can contribute to protect the environment), and socio-centric scope (i.e., how the system can support people's lives) [BCD+15].

Figure 1.4 shows growing awareness for indirect effects of software systems in the broader RE context. However, indirect effects have received much less attention in corresponding publications than direct effects [BCD+15]. In particular, indirect effects have least been considered with respect to the socio-centric scope [LP17]. To be able to shed more light on indirect effects, stakeholder participation is believed to be essential.

1.3.4 The Benefit of Stakeholder Participation

Ubiquitous software systems have a strong influence on society [SHK09]. For example, they can evolve towards complex distributed systems with unintended or unforeseen properties, and unpredictable consequences when turned off. As such, they particularly affect the socio-centric scope by the KMSD [BCD+15] and are potentially irreversible. Thereby, they increase the likelihood of effects that cause social risks and are considered unfavorable in terms of sustainable development [SHK09]. In this context, Som et al. [SHK09] emphasize the need for stakeholder participation. They argue that the participation of stakeholders in dialogues on the development of such novel software systems supports the "social robustness" of those systems.

Becker et al. [BBC+16] also highlight the importance of stakeholder participation in RE activities to address potential effects in a socio-technical context. They argue that collaborative stakeholder participation can significantly support long-term effects of software systems that are favorable to the transition towards sustainable development while mitigating the ones that are unfavorable.

To be able to foster the potential of stakeholder participation with respect to indirect effects of software systems and thereby, consider the socio-centric scope, they suggest the following guidelines:

1. When identifying stakeholders, identify also the stakeholders who do not utilize the system but are affected by its utilization;
2. Apply creative elicitation techniques that enable collaboration among stakeholders to (a) help them understand potential indirect effects of a software system and (b) support the prediction of those effects;
3. Maximize the heterogeneity and number of participating stakeholders to support the trade-off analysis.

This thesis coincides with these guidelines.

1.4 Motivation and Thesis Statement

The current state of the art in RE cannot sufficiently facilitate the collaborative participation of stakeholders outside organizational reach in RE activities. On one side, it reveals a *conceptual gap* by following a naive view of motivation. On the other side, it presents a *technology gap* by limiting collaborative stakeholder participation with respect to distributed setting and large-scales. While the former gap misses the high heterogeneity of stakeholders outside organizational reach, the latter neglects their location independence and potential large number. As a result, these gaps hinder the open and as such unrestricted and unlimited participation of stakeholders outside organizational reach in RE.

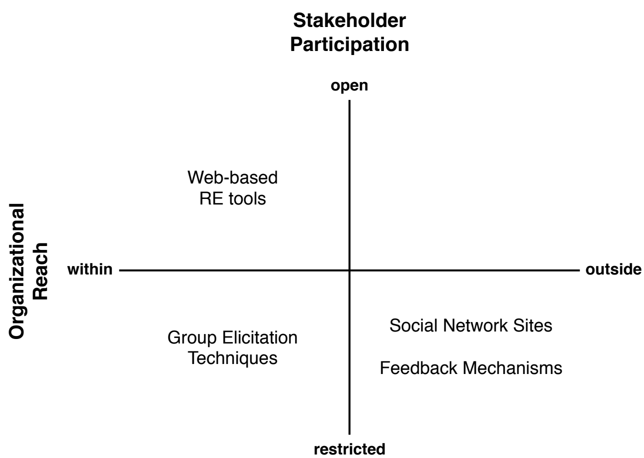

Figure 1.5: The void of approaches, which enable open collaboration in RE for stakeholders outside organizational reach

Figure 1.5 illustrates this void. It shows the approaches introduced in Section 1.2.3 and Section 1.2.4 classified in an abstract way. The classification first considers the organizational reach of the potentially participating stakeholders (x-axis) and then the freedom of their participation (y-axis).

For example, established group elicitation techniques [NE00] such as workshops and scenarios were designed to enable collaboration among stakeholders within organizational reach. In particular, they do not scale well and work best if the participating stakeholders are co-located. These criteria further limit the participation of these stakeholders.

Current Web-based RE tools typically scale well and work in distributed settings but again were designed for stakeholders within organizational reach. In particular, early Web-based tools such as WikiWinWin [YWK+08] and Athena [LBB09] lack means to explicitly motivate stakeholders to use them. More recent tools such as iThink [FDR+12] and REfine [SDB+15] address motivation with gamification. However, the motivation concepts of their gamification approaches are not designed for high heterogeneity.

Feedback mechanisms and social network sites (SNSs) can enable large-scale and distributed participation of stakeholders outside organizational reach in RE activities. Regarding motivation, feedback mechanisms do not necessarily apply a sophisticated concept but typically have the advantage of being embedded in the system for which they facilitate the feedback gathering. However, this also restricts them to the system users. Moreover, they are limited with respect to RE as they focus on software development.

In contrast, SNSs can support collaborative stakeholder participation in RE both for software development and evolution. They are also typically independent of the software system for which they are used. In terms of motivation, they originally are designed to connect people, which has a strong motivational potential that might at least partially transfer when using them for RE purposes. However, their original design is also what restricts them as it only enables their registered users to participate and provides limited support for RE purposes.

This thesis pursues the goal of providing an RE approach that truly facilitates the collaborative participation of stakeholders in RE. Such an approach considers stakeholders outside organizational reach and is open with regard to their participation.

In a world with digital equality [DH+01] this approach would support any stakeholder of a software system in participating collaboratively in RE activities that relate to the development or evolution of the system. To satisfy this condition the approach should be online accessible, designed for RE purposes, inform the stakeholders how to participate and provide means to motivate them to voluntarily participate. To achieve this goal we suggest the use of gamification and social media.

The thesis statement is therefore defined as follows:

> **Thesis Statement:** Gamification can be applied to social media platforms that facilitate open stakeholder participation such that stakeholders *outside* organizational reach are motivated to participate collaboratively on these platforms.

1.5 Thesis Goal, Methodology, and Research Questions

This section presents the research goal. It also introduces the research questions that were derived from the research goal to address the knowledge gaps of motivation and collaborative participation outlined in Section 1.2.3 and Section 1.2.4. Finally, this section describes the research methodology followed for this thesis and highlights the most important methodology steps.

The research presented in this thesis focuses on the collaborative participation of stakeholders outside organizational reach in activities that support the elicitation and prioritization of requirements. As discussed in Section 1.3 this implicitly considers the socio-centric scope of software systems with respect to sustainable development. The thesis statement, hence, extends to the field of *Sustainable Software Engineering* by Dick & Naumann [DN10] and in particular, to *RE4SuSy* by Penzenstadler [PMS13].

The research goal of this thesis is as follows:

> **Thesis Goal:** Develop an RE approach that facilitates distributed large-scale collaboration to elicit and prioritize requirements and uses a motivation concept which is tailored to stakeholders *outside* organizational reach.

To meet the thesis goal a research methodology inspired by Wieringa & Heerkens [WH06] was followed due to the following considerations: (i) A world problem exists that is represented by the gap between the *phenomenon* of stakeholder participation and its *norm*. In other words, there is a difference between how stakeholder participation is facilitated by the current state of the art and how it should be facilitated with respect to stakeholders outside organizational reach. (ii) Several knowledge problems are investigated with the research presented in this thesis to acquire the insights needed to address the identified world problem. (iii) These problems are operationalized with a set of research questions.

Five major steps that are presented in Figure 1.6 and explained in the following define the methodology. (1) *Problem investigation*: a rigorous inquiry is made regarding the nature of problems that need to be addressed to achieve the research goal. (2) *Solution design* & (3) *Design validation*: subsequently, a conceptual solution of a prototype is designed in an iterative process in which the preliminary design is created and single design elements are investigated to evolve it. (4) *Solution implementation*: next the conceptual solution is implemented as a technical solution. (5) *Implementation evaluation*: the prototype is tested in a real-world setting and the results evaluated with respect to the thesis goal.

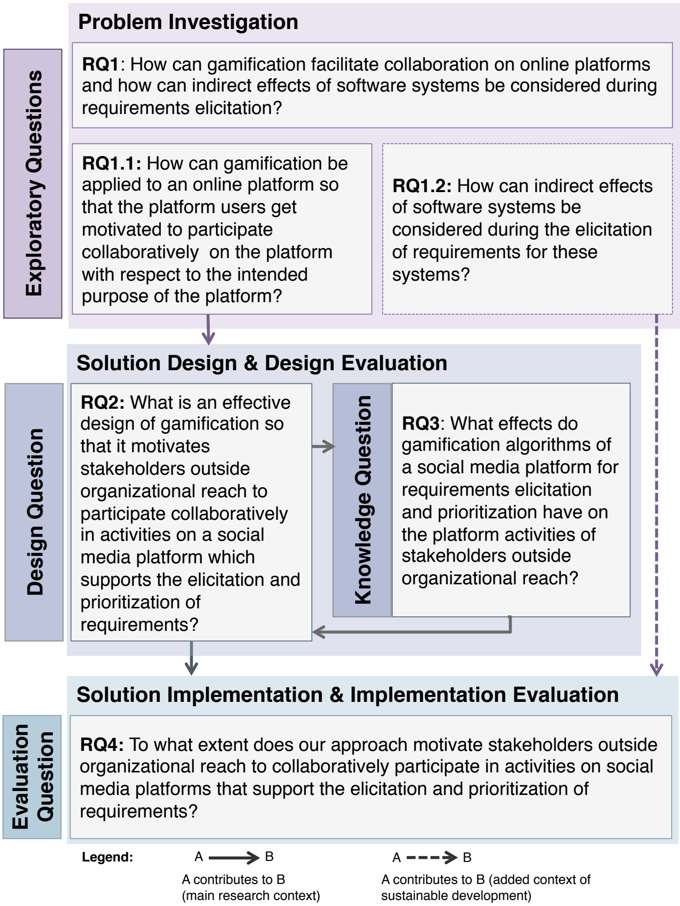

Figure 1.6: The research methodology with the research questions asked and the methods applied to operationalize the research problem, adapted after Wieringa & Heerkens [WH06] and Easterbrook et al. [ESSD08]

To support the methodology four main research questions were derived from the research goal as suggested by Basili [Bas93] and with regard to the categories developed by Easterbrook et al. [ESSD08]. Based on these categories the problem investigation was started with an *exploratory question*.

> **Research Question 1 (RQ1):** How can gamification facilitate collaboration on online platforms and how can indirect effects of software systems be considered during requirements elicitation?

To answer this kind of question it is essential to initially explore the application domain. Considering RQ1 collaborative participation is, therefore, investigated with focus on gamification (RQ1.1) and the process of requirements elicitation with respect to sustainable development (RQ1.2).

RQ1.1 helps to define basic design requirements for gamification with respect to the collaborative participation of stakeholders outside organizational reach in requirements elicitation and prioritization. Due to the lack of adequate research in RE, related fields had to be considered to answer the question. Once it was answered the defined design requirements were used to initiate the development of a corresponding motivation concept.

> **Research Question 1.1 (RQ1.1):** How can gamification be applied to an online platform so that the platform users get motivated to participate collaboratively on the platform with respect to the intended purpose of the platform?

RQ1.2 investigates different aspects of requirements elicitation with respect to indirect effects of a software system for which the requirements are elicited. With RQ1.2 the implicit contribution of stakeholder participation to the transition towards sustainable development as outlined in Section 1.3 is complemented.

> **Research Question 1.2 (RQ1.2):** How can indirect effects of software systems be considered during the elicitation of requirements for these systems?

A good gamification approach is one that bases on a motivation concept that is tailored to its users and considers its application domain. In order to meet the thesis goal a motivation concept must be designed that respects the heterogeneity of stakeholders outside organizational reach and considers the contexts of requirements elicitation and prioritization. The following *design question* [ESSD08] addresses this challenge.

> **Research Question 2 (RQ2):** What is an effective design of gamification so that it motivates stakeholders outside organizational reach to participate collaboratively in activities on a social media platform which supports the elicitation and prioritization of requirements?

To further improve the motivation concept, algorithms that control game elements were investigated. For this purpose a *knowledge question* [ESSD08] was asked.

> **Research Question 3 (RQ3):** What effects do gamification algorithms of a social media platform for requirements elicitation and prioritization have on the platform activities of stakeholders outside organizational reach?

Finally, an *evaluation question* [ESSD08] was asked to evaluate the developed approach with respect to the thesis goal and the findings from answering RQ1 – RQ3.

> **Research Question 4 (RQ4):** To what extent does our approach motivate stakeholders outside organizational reach to collaboratively participate in activities on social media platforms that support the elicitation and prioritization of requirements?

This research can be considered to be successful if the approach meets the requirements identified with RQ1.1, acknowledges the insights found with RQ1.2, applies the results obtained by answering RQ2 and RQ3, and if the evaluation of its results shows that it satisfies the thesis statement.

To get a better understanding of the research context the following section presents the approach, referred to as GARUSO approach, in a nutshell.

1.6 GARUSO in a Nutshell

This section introduces the GARUSO approach (***Ga**me-based **R**eq**u**irement**s** Elicitati**o**n*), which was developed to meet the thesis goal. The GARUSO approach has two parts: stakeholder identification and participation (see Figure 1.7). Both parts are described in the following and further explained with an example.

- Stakeholder identification. An identification strategy was created to support the identification of stakeholders outside organizational reach among different online communities.
- Stakeholder participation. The GARUSO Platform, a social media platform that applies gamification was developed to enable and motivate stakeholders outside organizational reach to participate collaboratively in RE activities.

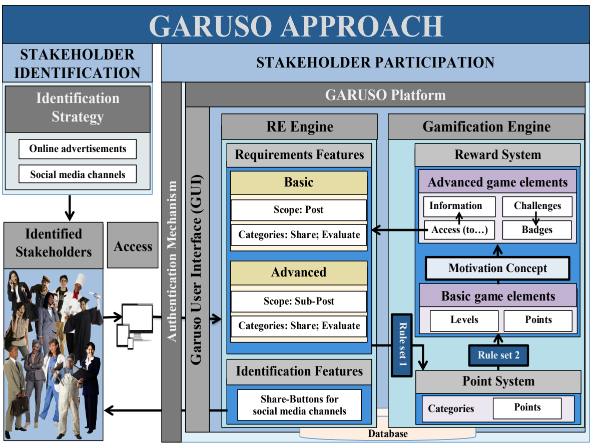

Figure 1.7: The GARUSO architecture (adapted after [HKG18])

1.6.1 Stakeholder Identification

The *Identification Strategy* (see the left part of Figure 1.7) uses diverse online channels such as e-mail services and SNSs to identify stakeholders of a software system who are outside organizational reach. It distributes information on the participation in RE activities on the GARUSO Platform for that system through these channels. This thesis suggests two courses of action to increase the effectiveness of this approach.

1. Select online channels that are used by people who are likely to be a stakeholder of the software system and distribute the information regarding the participation on these channels.
2. Select online channels that are used by people of whom the majority is not a stakeholder of the software system. Create online advertisements for personas of potential stakeholders to increase the chances of identifying actual stakeholders among the users of these channels. Subsequently, distribute the information regarding the participation together with the advertisements on these channels.

This identification strategy addresses the challenges described in Section 1.2.2. It also increases the effectiveness of the snowballing process in RE [LQF10a] as it provides a solution to identify initial key stakeholders across different online communities.

1.6.2 Stakeholder Participation

The core of this thesis is the GARUSO Platform. It is a social media platform that was developed to motivate stakeholders outside organizational reach with gamification to participate collaboratively in RE activities and to enable them to do so. The GARUSO Platform therefore addresses both the *conceptual gap* and the *technology gap* described in 1.2.3 and Section 1.2.4, respectively.

Figure 1.7 shows the two platform engines that were developed with each a different focus: RE and gamification. The former supports the elicitation and prioritization of requirements and enables the identified stakeholders to identify new ones. The latter manages the game elements and rewards on the platform. The *Requirements Features* facilitate five activities with respect to requirements elicitation and prioritization:

- Requirements Elicitation. The platform users can (1) *share posts* and (2) *share sub-posts* to express their needs and hence support the elicitation process. In this context "share" is a substitute for "create" as it emphasizes the collaborative nature of the GARUSO Platform.
- Requirements Prioritization. All platform users except the author can evaluate the shared contributions. This means, the platform users can (3) *rate posts*, (4) *vote posts* and (5) *vote sub-posts*. These evaluations depend on the subjective perception of stakeholders, which is why they are not considered as prioritization per se but rather as valuable contributions to the prioritization process.

The *RE Engine* is connected bidirectional with the *Gamification Engine*. On one side, the platform users' activities that are facilitated by the Requirements Features are transformed into points of the *Point System*. On the other side, the users are rewarded with access to new Requirements Features for these points.

This implies that the platform users *cannot* perform all RE activities from the beginning. In fact, between *earning points* and *getting access* is the *Motivation Concept*. It constitutes the core of the GARUSO Platform and is inspired by the *Experiential Learning Theory* by Kolb [Kol84], which considers a dual meaning of experience: the environmental meaning as in '20 years of experience in the job' and the personal meaning as in 'experiencing joy and happiness' (p. 35). The Motivation Concept considers the platform users' experiences during their participation with respect to these two meanings. It applies five levels of expertise and a design that facilitates experience-based rewards.

- Expertise levels. The platform users start as novice users on level I and may proceed up to level V, which is the expert level, by earning points for using the Requirements Features. This five-level approach considers the skill acquisition theory by Dreyfus [DD80], which states that when people follow the desire to acquire new abilities, they typically pass five stages of skill acquisition. The Motivation Concept uses these expertise levels as a metric to measure experience for the design of rewards. The underlying assumption is that with every reached level, the platform users increase their experience of using the GARUSO Platform. This, in turn, affects how they feel motivated.

- Experience based rewards. On every expertise level the platform users get access to new additional rewards. The Motivation Concept provides a guideline to design the rewards with respect to the levels. By taking the users' assumed experiences into account it increases the potential of the rewards to motivate the platform users to participate on the GARUSO Platform. With respect to the two meanings of experience, it considers two kinds of rewards: rewards that affect activities which directly relate to the application domain as, for example, access to Requirements Features (environmental meaning), and rewards that are defined by game elements as, for example, access to challenges or earned badges (personal meaning).

The Motivation Concept also considers that rewards of a gamification approach need to be meaningful to the users in order to be able to motivate them towards an intended goal in a non-game context [KTCK12]. It does so by taking the following four key points of motivation into account:

1. Motivation is affected by human needs which are hierarchically structured [Mas43];
2. Motivation is influenced by a mix of personality aspects and has changing states of fluctuating intensity [RD00];
3. Learning is an important aspect of motivation [DD80] and people learn by experience [Kol84];
4. People have characteristics that define how they act within the social world [Bro94] and that can also be found in the virtual world [FWG13, Bar04].

The Motivation Concept also enables the step-wise introduction of platform features to the participating stakeholders. This process of familiarization with a new environment is known as onboarding in game design [ZC11]. With respect to stakeholders outside organizational reach, onboarding is important, as these stakeholders can typically not be instructed in person by RE experts on how to participate in RE activities and how to use a corresponding RE tool or platform.

1.6.3 Example

The GARUSO Platform facilitates device independent, multi-language, asynchronous communication among its users. It has a responsive design that considers the screen size of the accessing device to support desktop and mobile devices alike and applies Google Translate to support multiple languages.

Figure 1.8 shows screenshots of the *entry page*, the *share page* and the *detailed page* of the GARUSO Platform. The screen shots are slightly adapted to improve their legibility[6]. Due to space constraints, only the screenshot of the entry page shows the top navigation bar and the sidebars but both bars also exist on the detailed page, and the former on the share page. The added letters indicate the activities that are enabled per page: **S**takeholder **I**dentification (SI); **A**ccess (A); **S**haring (S), **E**valuation (E). The three pages will subsequently be explained in more detail.

[6] A more detailed view is presented in our paper on the evaluation of the GARUSO approach [HKG18]

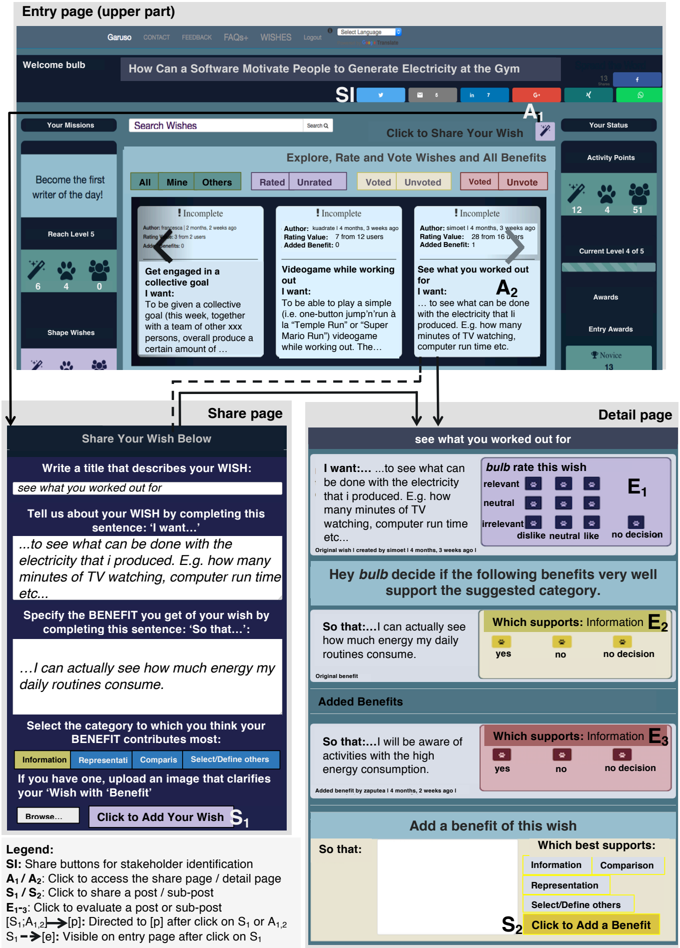

Figure 1.8: Screenshots of the entry page, the share page, and the detailed page of the GARUSO Platform adapted for legibility after [HKG18]

Entry Page. When the identified stakeholders log in to the GARUSO Platform they are directed to the entry page. Here, the two sidebars provide personalized information with the means of different game elements. They show RE activities that need to be performed to earn a next reward (left) and rewards that were already earned (right). From here the logged in stakeholders (in the following referred to as *platform users*) can choose between three RE activities:

1. **SI:** Stakeholder Identification. The top right part of the entry page shows seven buttons, each for a different online channel. Platform users who select one of the buttons can spread the information about the RE process on the GARUSO Platform among the users of the corresponding online channel.
2. **$\mathbf{A_1}$:** Access the share page. Beneath the share buttons is a single button showing the icon of a wand. Platform users who select the button are directed to the share page.
3. **$\mathbf{A_2}$:** Access the detailed page. The center of the entry page displays truncated versions of shared posts in randomly alternating groups of three. Platform users who select one of these posts get to the detailed page of the corresponding post where the full post is shown with all of its sub-posts.

Share Page. To share a post platform users need to complete the form on the share page. In Figure 1.8 the italic text and the yellow colored button give an example of a completed form. The form structure is inspired by the structure of user stories. This means, platform user first need to describe a wish followed by a benefit, which they believe to experience if the wish is fulfilled. To complete the form they also need to select a label that indicates the context to which they think the benefit contributes the most. A set of labels from which they can choose from is available at the bottom of the form. Expert users can also add labels. Optionally, an image can be uploaded to visualize the wish.

1. $\mathbf{S_1}$**:** Share a post. The platform users can share a post by clicking on the share button with the label *Click to Add Your Wish.* If the form was completed as described above the post will be saved. In this case the post becomes instantly visible on the entry page to all the other platform users and the author of the post is directed to the detail page of the post.

Detail Page. Here the platform users see the full post, which includes its title, the wish part and the benefit part with its contribution label, as well as any sub-posts. On the GARUSO Platform every sub-post of a post adds a further benefits to the wish that is stated in that post. Hence, sub-posts extend the user story that was original described with a single post. On the detailed page the platform users can add sub-posts and perform up to four evaluation activities ($E_{1\text{-}3}$). The expertise level of a platform user defines which RE Features are enabled. However, evaluation activities are only enabled for (sub-) posts of which a user is not the author.

1. $\mathbf{E_1}$**:** Rate a post. The platform users can rate the wish part of a post along two independent dimensions. This enables them to state how relevant they perceive the wish (y-axis) and whether they personally like it (x-axis).
2. $\mathbf{E_2}$**:** Vote on a post. Platform users on expertise level II or above can also vote on the benefit contribution label of a post. The vote options are: *vote for*, *vote against*, *undecided*.
3. $\mathbf{E_3}$**:** Vote on a sub-post. Similarly, platform users on expertise level III or above can vote on the benefit contribution label of a sub-post.
4. $\mathbf{S_2}$**:** Share a sub-post. In terms of sharing, platform users on expertise level II or above can share sub-posts and as such extend the list of benefits of a user story.

1.7 Roadmap and Chapter Summary

This thesis is cumulative. It consists of five scientific publications, which contribute to the three domains of RE, Gamification and Sustainable Development (see Figure 1.9). Each of the publications constitutes a chapter of the thesis, followed by the Conclusions. The four papers presented in Chapters 2 – 5 are each peer-reviewed and published. They support the thesis goal and additionally present stand-alone research contributions. Chapter 6 is a working paper that was submitted to a journal for publication.

This section gives an overview of the five chapters. For every chapter it outlines the motivation and summarizes the research approach that was taken together with the contribution of the research presented in that chapter. It also shows which of the research questions previously defined and referenced in Section 1.5 are answered per chapter.

Figure 1.9 shows the roadmap of this thesis. It illustrates the methodology steps, research questions, and chapters with respect to the three domains: RE, Gamification, Sustainable Development.

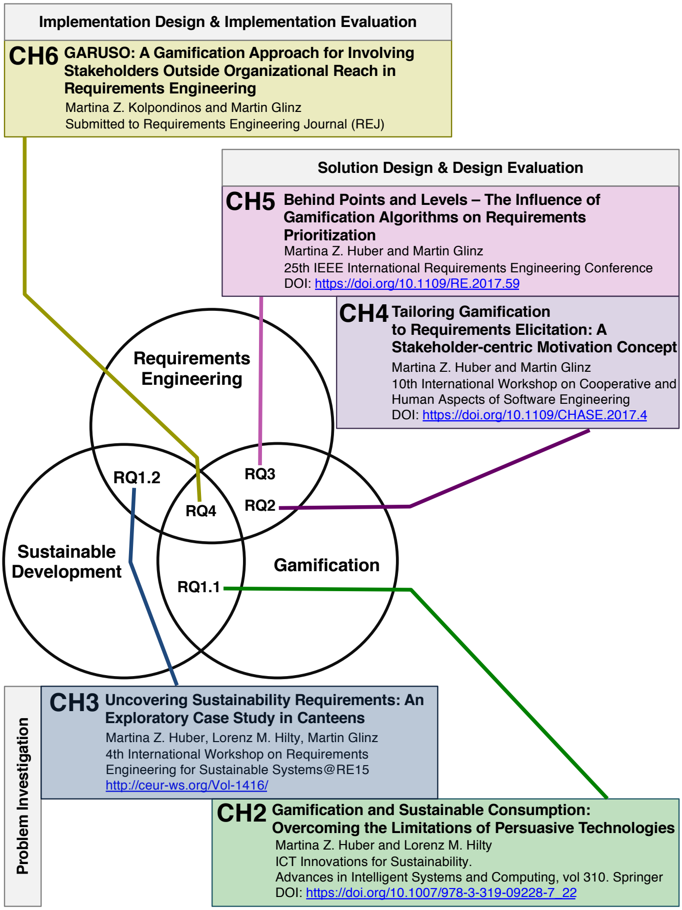

Figure 1.9: The roadmap showing the five chapters (CH2-CH6) with respect to the methodology steps (gray bars), the research questions (RQ1-4) and the domains (RE, Gamification, Sustainable Development) of this thesis

Chapter 2: Gamification Beyond Persuasion

Motivation: Motivational strategies are vulnerable to the designers' objectives. Designers of software systems with rigid motivation strategies assume that they are more competent than the end-users of the systems. This concept is known as *technology paternalism.* The ethical dilemma of technology paternalism is reflected by the trade-off between either imposing a solution or path, which challenges an end-user's autonomy and, not imposing it, which can hinder opportunities that might be in the best interest of the end-user [Hil15].

Approach: To address the challenge of technology paternalism in the scope of the thesis goal we need to understand the concept of motivation better, especially with respect to gamification. Therefore, we first conducted a *literature overview* in the fields of psychology, persuasive technology, eco-feedback technology, and game design. Next, we assessed our findings against prototypes and applications from academia and industry that apply motivational strategies.

Contribution: This chapter answers RQ1.1. It represents the core of the *problem investigation* of the methodology followed in this thesis and builds the foundation of the conceptual solution. The main contribution of this chapter is a set of basic design requirements for gamification, which consider stakeholders outside organizational reach. These requirements help designers to motivate end-users of social media platforms towards the platform purpose while respecting the users' autonomy.

Chapter 3: Uncovering Sustainability Requirements

Motivation: The interweaving of ubiquitously deployed and openly available software systems with people's lives has increased the awareness for indirect effects of these systems. Researchers from different fields consider the participation of stakeholders outside organizational reach in RE, especially in requirements elicitation, as essential to effectively address these (potential) effects and to help anticipating them.

Approach: To shed light on how these effects can be considered during requirements elicitation we conducted an *exploratory study*. In the scope of a real-world case study, we used different elicitation techniques to help evolving a software system with respect to its indirect effects[7].

Contribution: This chapter answers RQ1.2. It adds to the broader context of the *problem investigation* of the methodology followed in this thesis. Thereby, it supplements the technical solution of our GARUSO approach with information on how to address (potential) indirect effects of a software system during requirements elicitation. The main contribution of this chapter is a set of uncovered aspects of software requirements that help stakeholders to label their wishes and needs with respect to these effects. The results also indicate the importance of engaging stakeholders outside organizational reach in RE activities to effectively address indirect effects of a software system.

[7]The software system is used in a working environment. It was evolved with the goal to support and motivate the employees who use it to make CO_2 friendly business decisions when using it.

Chapter 4: A Stakeholder-centric Motivation Concept

Motivation: A successful gamification approach creates a virtual link between the non-game context and the game context. Research results from motivational psychology strongly suggest that such an approach needs to consider different experiences and personality aspects of its (potential) users. With respect to the thesis goal the design of a motivation concept, which addresses a highly heterogeneous crowd, is of main interest.

Approach: We explored different aspects of human motivation by investigating acknowledged theories from the fields of motivational psychology, learning psychology and economy together with best practices in game design. By bringing the findings together we derived a three-dimensional motivation concept that is tailored to stakeholders outside organizational reach.

Contribution: This chapter adds knowledge to answer RQ2. It represents the *solution design* of the methodology followed in this thesis. As its main contribution it provides an early version of the Motivation Concept, which later was evolved and applied to the GARUSO Platform. The concept presented in this chapter builds a basic framework for the design of rewards to motivate stakeholders outside organizational reach with respect to their heterogeneity, in the non-game context and the game context, and over time.

Chapter 5: Behind Points and Levels

Motivation: RE experts in industry and academia show increasing interest in how stakeholders can be motivated to participate in RE. Gamification offers a valuable solution for this purpose. Yet, research on gamification in RE is still in its infancy. Especially little is known about the influence of algorithms that control the applied game elements on the stakeholders' activities. This lack of knowledge increases the threat to demotivate stakeholders to participate in RE who initially were motivated to do so.

Approach: We addressed the threat of what we refer to as "demotivation by gamification" by investigating the effects of four gamification algorithms with a *field experiment*. To run the experiment, we developed an early version of the GARUSO Platform on which two independent groups of stakeholders participated. Both groups had identical RE tasks for which they were motivated with the same two strategies. These strategies were each implemented with a different gamification algorithm per group. All participants can be considered stakeholders outside organizational reach.

Contribution: This chapter answers RQ3 and adds knowledge to answer RQ2. It represents the *design evaluation* of the methodology followed in this thesis. The results presented in this chapter show statistically significant differences between the gamification algorithms on the activities taken by the participating stakeholders. The main contributions of this chapter also include indications for a pattern on how stakeholders feel motivated in RE over time, which was later used to evolve the Motivation Concept described in Chapter 4.

Chapter 6: GARUSO

Motivation: We wanted to know the effectiveness of the GARUSO approach in a real-world setting with respect to the thesis goal.

Approach: To determine the effectiveness we implemented the conceptual solution of the GARUSO approach with the GARUSO Platform as a prototype and evaluated it in a *field study*. The platform considers the results presented in Chapters 2 and 3 together with the Motivation Concept created in Chapter 4 and was evolved with findings from Chapter 5. To identify stakeholders outside organizational reach, we created a strategy that is inspired by the personas introduced in Chapter 4 and practices used in online marketing. The main evaluation criteria for the GARUSO approach investigate who the visiting and participating stakeholders are, how they interact with the platform and how they perceive the applied gamification approach.

Contribution: This chapter answers RQ4. It represents the *solution implementation* and the *implementation evaluation* of the methodology followed in this thesis. The results of the field study show that the GARUSO approach engages stakeholders beyond organizational limits. It provides a strategy that supports the identification of stakeholders outside organizational reach and uses a concept that successfully motivates and enables them to collaboratively participate over time in RE activities. The evaluation results also contribute first design principles that support future research in the field of CrowdRE with focus on stakeholders outside organizational reach.

1.8 Contributions

The main contribution of this thesis is the GARUSO approach, an RE approach that facilitates stakeholder participation beyond organizational limits. The GARUSO approach supports the identification of stakeholders outside organizational reach and facilitates their collaborative participation in RE activities. Our main contribution has three major aspects:

(1) The conceptual solution of the GARUSO approach. It defines the Identification Strategy and the GARUSO Platform.

- The Identification Strategy derives from the snowballing process but enhances it by enabling the identification of initial stakeholders across online communities and independently of knowing them.
- The GARUSO Platform consists of the platform architecture with the RE Engine and the Gamification Engine. As such it merges the RE context with the game context while considering different personality aspects of stakeholders outside organizational reach.

(2) The technical implementation of the conceptual solution. It is represented with the prototype of the GARUSO Platform.

(3) An evaluation of the implemented solution. It shows how effectively the GARUSO approach supports the identification of stakeholders outside organizational reach and how it facilitates their collaborative participation in RE activities with respect to requirements elicitation and prioritization.

In addition to the main contributions this thesis also contributes

- a set of basic design requirements for gamification approaches which aim at effectively motivating end-users of social media platforms towards collaborative activities on these platforms, with Chapter 2;
- a set of aspects for requirements that help stakeholders to support addressing (potential) indirect effects of software systems during the elicitation process, with Chapter 3.

Chapter 2

Gamification Beyond Persuasion

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Gamification and Sustainable Consumption: Overcoming the Limitations of Persuasive Technologies

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Abstract

The current patterns of production and consumption in the industrialized world are not sustainable. The goods and services we consume cause resource extractions, greenhouse gas emissions and other environmental impacts that are already affecting the conditions of living on Earth. To support the transition toward sustainable consumption patterns, ICT applications that persuade

consumers to change their behavior into a "green" direction have been developed in the field of Persuasive Technology (PT). Such persuasive systems, however, have been criticized for two reasons. First, they are often based on the assumption that information (e.g., information on individual energy consumption) causes behavior change, or a change in awareness and attitude that then changes behavior. Second, PT approaches assume that the designer of the system starts from objective criteria for "sustainable" behavior and is able to operationalize them in the context of the application. In this chapter, we are exploring the potential of gamification to overcome the limitations of persuasive systems. Gamification, the process of using game elements in a non-game context, opens up a broader design space for ICT applications created to support sustainable consumption. In particular, a gamification-based approach may give the user more autonomy in selecting goals and relating individual action to social interaction. The idea of gamification may also help designers to view the user's actions in a broader context and to recognize the relevance of different motivational aspects of social interaction, such as competition and cooperation. Based on this discussion we define basic requirements to be used as guidance in gamification-based motivation design for sustainable consumption.

2.1 Introduction

The goods and services consumed in industrial societies are the main cause of global environmental impact. Sustainable consumption and production aims at changing "unsustainable patterns of consumption and production" and requires "fundamental changes in the way societies produce and consume" in order to "achieve global sustainable development" [UNE10, p. 12].

ICT applications have been developed to support users in this imperative change towards sustainable consumption. Specifically, eco-feedback technologies and so-called Persuasive Sustainability Systems (PSSs), which are Persuasive Technologies (PTs) in the field of sustainability, aim at inducing users to more sustainable behavior. Whereas eco-feedback technologies have primarily focused on raising awareness by providing information on measurable aspects of sustainability, PSSs go beyond this and suggest predefined actions typically designed to achieve a rational goal. Within current implementations these two technologies usually merge, as in the cases of UbiGreen [FDK+09], a mobile phone application supporting "green" choices of transport modes or features in Toyota cars which encourage eco-friendly driving [Fog09]. Recently, community-based approaches encouraging environmentally friendly actions, particularly in regard to reducing residential electricity usage have increasingly been discussed within the field of ICT. Eco-feedback and PT have been expanded to the Internet, sharing usage data and comparing it with predefined benchmarks and social norms.

Examples include WattsUp [FLBC10], which focuses on social norms and StepGreen.org [MFD+10], which additionally suggests actions that "may save money or energy" (p. 2).

In spite of the widely acknowledged desirability of encouraging sustainable behavior, PT has been criticized for several limitations. These involve, in particular, an oversimplified and isolated view on behavior due to focusing on clearly measurable aspects, the inherent technology paternalism and the lack of solution building [BHP+12, Bog10]. These limitations will be explained in more detail later.

The design of ICT solutions to support people in behavior change needs to be approached in a more comprehensive way. Instead of focusing only on predefined solutions, the context of the process causing the consumption has to be analyzed. This requires additional engagement strategies, the (social) context of an action and the user's cognitive, emotional and social capabilities. Research has shown that games have a high potential for engaging people in a wide variety of ways.

Games tap into the world of "fun", affect emotions and have the ability to involve users more deeply. At the same time they have the potential to motivate users toward a specific course of action without dogmatism [BHP+12]. Gamification is the use of game or game design elements in non-game contexts and has recently become of increasing interest within ICT. "Assuming that people like to play but are confronted in their everyday life with non-motivational activities, gamification is the process that induces motivation in those activities" [SRV13, p. 3].

Gamification does not say anything about how to use game elements in the non-game context or what the non-game context has to be. As a result gamification-based approaches can be found in a wide range of applications. Approaches include loyalty programs (e.g. collecting miles in frequent-flyer programs or stamps in super markets), systems encouraging customers to share information (e.g. showing progress bars and scores such as in LinkedIn [1] and ResearchGate [2]), or motivating consumers to eco-friendly driving behavior (e.g. providing information on average consumption as Toyota does [Fog09]) or to reduce electricity consumption (e.g., by enabling normative comparison as done by Opower [3]).

As a matter of fact, all of these gamification-based approaches are rooted in PT-based design. Depending on the perspective, it could also be argued that recent PT-based approaches include gamification-based ideas (see for example [FDK+09, Fog09, FLBC10]). Regardless of where the line between PT and gamification is drawn, all the examples previously mentioned inherit the limitations of PT-based design.

In this chapter, we elaborate requirements intended to guide the design of a gamification-based approach, which motivates sustainable consumption while overcoming the present limitations of PT. Sustainable consumption is embedded in, and influenced by, a complex structure of regulations, communities, large enterprises, and other stakeholders. All of these entities affect a consumer's decision-making process and in their turn may be influenced by it.

[1] http://linkedin.com/
[2] http://researchgate.com/
[3] http://opower.com/

Figure 2.1: Information comparison as a persuasion technique (Source: [Rad])

We believe that in order to achieve sustainable consumption it is important to take into account the influences of all these entities. Our research focuses on the potential role of gamification in this context.

The chapter is organized as follows: Section 2.2 provides some background on PT and discusses the major limitations of PT; we focus on limitations we consider to be relevant, at least in the context of sustainable consumption. Section 2.3 gives an overview of gamification. Section 2.4 provides examples of first attempts to introduce gamification into the field of sustainable consumption. Section 2.5 elaborates basic requirements for gamification-based approaches to sustainable consumption that can guide designers who want to overcome the limitations of PT-based approaches. Finally, section 2.6 provides preliminary conclusions and identifies open research questions.

2.2 Persuasive Technologies

2.2.1 Background

The concepts we introduce below are based on Fogg's work on captology [Fog98] – the study of computers as persuasive technology.

Persuasion. Fogg defines persuasion as "an attempt to change attitudes or behavior or both (without using coercion or deception)" (p. 15). Thereby, intention to change attitudes or behaviors is seen as a necessary condition for persuasion. The goal of persuasion is to generate intentionally planned attitude and behavior changes [Fog98, Fog03] "Self-persuasion" is a specific form of persuasion in which a person already agrees with the values directing the behavior change and the persuasive system is used in order to "overcome a weakness of the will" [Spa12, p. 645].

Persuasive Systems. Based on the definition of "persuasion", PT can be defined as an "interactive computer system [technology] designed to change people's attitudes and behaviors" [Fog03, p. 1]. Thereby, PT "focuses on the attitude and behavior changes intended by the designers of interactive technology products" (p. 17). As an example, Fig. 2.1 shows a speed monitoring system. The underlying goal is to raise drivers' awareness of their speed and implicitly suggesting driving at the maximal indicated speed limit. Specific applications of PT are usually called "persuasive systems".

The application of PT in the domain of ecological sustainability has created the special case of "persuasive sustainability systems" (PSSs). Contemporary PSSs are described as "technologies that sense, interpret, and respond to human activity by providing information intended to change the behavior of individual consumers according to a metric selected in a top-down fashion usually defined as reducing resource consumption" [BHP+12, p. 950].

Eco-feedback Technology. Eco-feedback technology provides information (e.g. by mobile phones, ambient displays, or online visualizations) about individual or group behavior and its environmental effects. These applications are based on the assumption that their users lack awareness and understanding of the environmental effects of their everyday behavior [FFL10, p. 1999]. Research on eco-feedback has its roots in environmental psychology and – as some authors claim – may improve PT research [FFL10]. Whereas eco-feedback systems have the character of raising awareness, PSSs tend to persuade consumers to change their behavior in order to achieve a specific system goal.

Communicating with vs. Communicating through Computers. Persuasive and eco-feedback technologies are important in human-computer interaction (HCI) research. In HCI, the focus is mainly on people's interaction with computer systems [Fog03]. Fogg makes a distinction between this view and the paradigm of computer-mediated communication (CMC). In the first case, the system is viewed as a "participant in the interaction and possible source of persuasion", able to "proactively seek to motivate and influence users, drawing on strategies and routines programmed into it [e.g. by incentives or negotiations]." [Fog03, p. 16].

In the second case, the focus is on people's interaction through computer systems, which are used "as a channel that allows humans to interact with each other (e.g. instant messaging and electronic whiteboards for collaboration)" [Fog03, p. 16]. While captology – the study of computers as persuasive technology – investigates how people are persuaded when interacting with computers, we consider that both aspects are equally relevant to a gamification-based approach.

The Scope of Consumption. Consumer behavior has been a subject of research in the fields of evolutionary psychology, anthropology and sociology. In a nutshell, there is high evidence that consumer behavior is mainly influenced by

- Symbolic roles and cultural meanings of consumer goods (e.g. McCracken [McC86])
- Social and sexual competition (e.g. Penn [Pen03])
- Continual process of constructing and reconstructing personal identity (e.g. Soron [Sor10])

Individual decisions and actions are rooted in routines and based on affective and emotional bursts. They evolve from the complex structure of socio-cultural and socio-economic influences and rely on restrictions due to constraints (e.g. regulations) or current unavailability of possibilities (e.g., due to low income).

PT is usually based on the implicit assumption that information causes behavior change – or at least a change in awareness and attitude that will then cause behavior change. Against the background of the views cited, this looks like a reversion to the era of psychological behaviorism.

2.2.2 Limitations of PT-based Approaches to Sustainable Consumption

In this subsection, we present an overview of aspects of PT-based approaches discussed in the literature with a focus on issues we consider particularly limiting in the context of sustainable consumption.

Focus on Measurable Effects. PT-based approaches applied in the field of sustainability usually rely on measurable effects declared as sustainability indicators, for example how much of a resource such as electric energy has been used. The measured data, typically in regard to a benchmark, usually works as a trigger for system actions (e.g. a list of predefined "solutions" such as turning off the lights), with the intention of persuading consumers to move toward the system goal (such as reducing energy consumption).

Measurements are becoming more and more fine-grained, allowing more tailored interventions by PT. In the domain of residential electricity consumption, an approach called Non-Intrusive Load Monitoring (NILM) is becoming popular. The goal of NILM is to recognize household appliances based on their "energy signature". Machine learning algorithms applied for this purpose have been improved over the last years. However, accuracy is still an issue, especially if appliances are new and/or have similar signatures [CRJ12] (e.g., dryer and oven [KOO13]). Furthermore, satisfactory answers to privacy concerns are still missing [FDAR11].

Despite improvements in such technologies, with a too narrow focus on measured output, even with 100% accuracy in NILM, interpretation of the meaning attached to an action (e.g. reason, intention and kind of action) and analysis of the process causing the consumption become very difficult or even impossible.

Assumption of Rational Choice. PT-based approaches are often based on the implicit assumption that consumers are rational actors whose only goal is to optimize their activities based on their preferences and knowledge [BHP+12]. "Rational choice models assume that human behavior is regulated by a systematic process of evaluating expected utility." [FFL10, p. 2000]. Under this assumptions rational actors in any given situation only take actions that provide the biggest personal gain at the least personal cost. Evidence shows that "ordinary people in ordinary situations are simply not capable of processing all the cognitive information required for so-called 'rational' choices." [Jac05, p. 36]. Benkler [Ben09] argues that under the homo economicus assumption, volunteer work for peer-production projects such as Wikipedia[4] would not exist. Even though there are people who show a behavior based on purely selfish choices – a limited form of rational choice –, research has shown that this applies to only one third of the population [Ben09].

Feeding back data from measurable aspects of sustainability makes sense under the assumption of purely rationally motivated consumers.

[4] http://wikipedia.org/

However, consumers are diversely motivated, and the interpretation of change in measured output under the isolated assumptions of rational choices loses sight of the broader motivational aspects of human behavior, and may lead to ineffective action triggers produced by the system (e.g. predefined “solutions” which have no meaning to consumer).

Insufficient Account of Individual Differences and Social Context. PT-based approaches are for the most part built on a foundation that information will trigger a predetermined interpretation and action in all consumers. This assumption can only be made if consumers are seen as identical and isolated agents. In reality, though, consumers come with a “variety of backgrounds, desires, and skillsets” [Nic12, p. 225] and their decisions are influenced by their individual and collective identity. Identity in this context is “the meanings one has as a group member, as a role-holder, or as a person” and part of the self which emerges from social interactions [SB03, p. 8]. According to Greenwald and Pratkanis [GPWS84], the self consists of three different aspects:

- public: *‘people [parents, peers, authorities] think I... ’*,
- private: *‘I [my inner audience for behavior] think I... ’*,
- collective: *‘my family [reference group] thinks I... ’*.

The development and influential power of these aspects depend on cultural variation, specifically on the complexity, the level of individualism, and the looseness of a culture.

Based on this view of humanity, it can be assumed that the more all three dimensions are developed, the more likely it is that people will express their private self [Tri89]. No individual self can exist without social relations. Mead views the self as “something which has a development; it is not initially there, at birth, but arises in the process of social experience and activity (...)” [Mea62, p. 1]. Baumeister and Leary point out the importance of the need to belong, which “can be considered a fundamental human motivation” [BL95, p. 521].

Within the design structure of PT-based approaches, while focusing on measurable aspects of sustainability and assuming consumers are purely rationally motivated, it makes sense to consider consumers as uniform agents. However, ignoring the complex interaction between the individual, groups and society locks out major consumer segments and may not lead to solutions that can sustain motivation over a long period.

Paradigm of Raising Awareness and Changing Attitudes. PT-based approaches are typically designed following the paradigm that raising awareness and changing attitudes are the main drivers for behavior change. Research, however, has shown that behavior change does not necessarily come from raised awareness [YSAL13], nor from a change in attitude [ZOF81]. In fact, the actual influence of awareness on any change in behavior is usually unclear since other factors may also have played a [unknown] role [BHP+12].

Empirical results suggest that some behaviors are induced neither by attitude nor intention; on the contrary, observations have shown that “although the attitude-to-behavior connection is not very substantial, the behavior-to-attitude link has been shown to be quite strong” [ZOF81, p. 253]. For example, “people may recycle simply as a result of changes in municipal waste collection services, without ever having decided that recycling is a good thing” [Jac05, p. viii].

A too narrow focus on awareness and attitude, assuming purely reactive consumers, misses the power on consumer’s decisions deriving from a broad field of various influences. As pointed out before, influences derive from structures into which consumers are integrated such as communities, major corporations, rules and regulations. Moreover, purely focusing on awareness and attitude misses the motivational power given by pro-active engagement opportunities.

Inherent Technology Paternalism. PT-based approaches applied in the field of sustainability are mostly based on the implicit assumption that the designers of the application start from objective criteria for “sustainable” behavior and are able to operationalize them in the application context. The evaluation of the consumer’s actions according to these criteria is delegated to the system in order to automatically rate the impact of an action and to recommend alternatives. In this process, “the designer seems to be de facto more knowledgeable about sustainability than the users of PSSs” [BHP+12, p. 953]. This attitude is referred to as “technology paternalism”.

Paternalism is a concept used in ethics, describing an attitude involving imposition of solutions to assumed problems on other persons even without their consent.

The underlying ethical dilemma arises from the fact that an imposed solution on one side clearly “violates the autonomy of the other person”. On the other hand, “by not imposing [the solution] one may not do the best possible in the interest of the other” [Hil15].

2.2.3 Potential for Improvement

PT persuades people rather than creating opportunities for negotiation, reflection and self-conviction. Thereby, the question arises “where to draw the fine line between persuasion and manipulation.” [15, p. 634]. Furthermore, PT assumes “that the user has already understood and accepted the larger reason that the technology inscribes” [Bog10, p. 61].

Consequently there is room for innovation to tap a much greater potential for motivating and supporting sustainable consumption through ICT- based solutions.

2.3 Gamification

In the field of residential energy consumption, systems with the goal of motivating pro-environmental behaviors have evolved from eco-feedback technologies for electricity consumption such as early ambient displays (e.g. The Power Aware Cord [GG05]) and sophisticated remotely accessible In-Home Displays (IHD) to more actively persuasive systems such as EcoIsland [TLS^{+}09], “a system for persuading users to reduce CO2 emissions” (p. 59). Recently, especially because of the motivational and engaging character of games, gamification-based design has become of increased interest in this field.

In the following we are going to outline basic design requirements to overcome the limitations of PT to sustainable consumption. Gamification-based approaches have been developed in different fields. The requirements may not be transferable to all of them e.g. approaches to prevent adolescents from substance abuse and relationship violence [SBBEL13] or to encourage engagement in online debate systems [TCB14].

In Sect. 2.3.1 we give background information on gamification with a focus on motivational aspects of games being of interest for gamification-based approaches to sustainable consumption. To give a better understanding in how to apply the theoretical background in the physical world Sect. 2.4 provides first examples to introduce gamification into the field of sustainable consumption. Finally, Sect.2.5 follows with an outline of basic requirements for these systems to overcome the limitations of PT.

2.3.1 Background

Whereas the field of gamification has already been implicitly introduced over the last decades, its terminology is new [ZC11]. One of the most conclusive and most frequently cited definitions of gamification is given by Deterding et al. [DDKN11]: "Gamification refers to the use (rather than the extension) of design (rather than game-based technology or other game-related practices) elements (rather than full-fledged games) characteristic for games (rather than play or playfulness) in non-game contexts (regardless of specific usage intentions, contexts, or media of implementation)." (p. 13).

This definition gives a formal understanding of gamification, it does not restrict the aim or scope of a gamification-based system. So far more common in loyalty programs such as frequent flyer programs, recently, the field of gamification has expanded beyond such programs and gained interest in another area: motivating and engaging consumers.

The goal of gamification in this newer area is to engage consumers in the *process of developing their own behaviors*, and it does this by "the process of using game thinking and game mechanics" [ZC11, p. 9]. Gamification does not necessarily require interaction with an ICT system, as the examples of frequent flyer programs and discount stamps show. However, in the following, we will implicitly refer to gamification as an *ICT-based approach.*

Playing or Gaming? According to Deterding and colleagues, playing (from the Greek term "paidia") refers to a free form of expression, allowing improvisational recombination of different behaviors and meanings, in contrast to gaming (from the Latin term "ludus") [DDKN11]. However, there are no generally accepted definitions of these concepts, even after millennia of thinking and talking about them [Sch14]. In the words of Lehman and Witty [LW27]: "The whole truth' regarding play cannot be known until the whole truth regarding life itself is known, for play is; not an isolated phenomenon." (p. 7). We will rely on the following tentative definitions of the concept of game:

- "A game is a problem-solving activity, approached with a playful attitude'. Thereby, 'play' is defined as 'manipulation that satisfies curiosity." [Sch14, p. 37]
- "A game is a rule-based formal system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome, and the consequences of the activity are optional and negotiable." [Juu10, p. 5]

Game Elements. Schell [Sch14], based on various definitions of games, identifies ten elements of a game: "Games are entered willfully, have goals, have conflict, have rules, can be won and lost, are interactive, have challenges, create their own internal value, engage players and are closed, formal systems" Similarly, McGonigal [McG11] proposes four defining traits which all games have in common: "a goal, rules, a feedback system and voluntary participation" (p. 20).

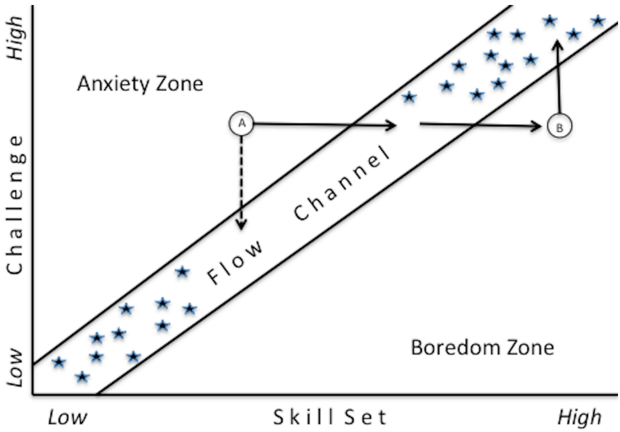

Figure 2.2: Flow (Source: author, based on [Csi90])

The Motivational Power of Games. Despite there is no consensus on how to define "game", there is a wide consensus about the motivational power of games [RRP06]. Motivational aspects are manifold, their power depends on diverse influences such as context, interface design and genre, and they can be introduced by different means. We will elaborate on crucial motivational aspects in the following subsections.

Flow. According to McGonigal [McG11], the power of a good game is that it "motivate[s] us to participate more fully in whatever we're doing" (p. 125). In fact, researchers in the area of neuropsychology have found evidence that playing video games can release Dopamine, a neurotransmitter, which "may be involved in learning, reinforcement of behavior, attention, sensorimotor integration and activation of the pleasure circuit" [KGL+98, p. 266].

This intense neurochemical activation in our brain and body while playing a good game [McG11] has been referred to as state of flow. *Flow* expresses a state of being completely absorbed in what one does [Csi90]. It can be experienced within a small channel between anxiety and boredom and depends on personal (player) skills in regard to a challenge (Fig. 2.2). Flow is individually experienced and can happen in any kind of situation, including non-game activities.

According to this concept, a person (player) in position A (Fig. 2.2). will try to improve her or his skills in order to reach the channel of flow for the chosen challenge. This is illustrated in Fig. 2.2 by the solid arrow pointing from position A to the right. A second possibility would be to choose an easier challenge (illustrated by the dashed arrow pointing from position A downwards (Fig. 2.2)), but in practice this solution seems to be less likely [Csi90]. By further improving the skills, a challenge might be mastered and become boring. In this scenario, the person (player) moves away from the flow channel and ends up at position B (Fig. 2.2). To go back to the channel of flow, a harder challenge has to be chosen, indicated by the solid arrow pointing from position B upwards (Fig. 2.2).

Player Types. Based on the observation that different players find different things fun, Bartle developed an extended concept of different player types. In his basic model he hypothesizes that four different player types do exist.

Table 2.1: Bartle's Player Types

Original Player Types [Bar96]	New Implicit Types [Bar05]	New Explicit Types [Bar05]
Achievers want to gather as many points as possible and level up.	**Opportunists** look around for things to do and if they see an opportunity, they take it. They avoid obstacles.	**Planners** set a goal and aim to achieve it. They perform actions as part of a larger plan and work around obstacles.
Explorers prefer to expose the game's internal machinations.	**Hackers** seek to discover new phenomena by going where their fancy takes them and have an intuitive understanding of the virtual world.	**Scientists** actively form theories and test them. They methodically acquire new knowledge and seek to explain phenomena.
Socializers like to connect with other people.	**Friends** "interact with people they know well already, have a deep understanding of them, and accept their quirks and foibles."	**Networkers** make an effort to find people with whom to interact, learn from, and hang out.
Killers like to impose themselves on others.	**Griefers** love to attack and get in your face. Their vague aim is to acquire a substantial bad reputation.	**Politicians** manipulate people subtly through forethought and foresight. They want to contribute to the community and get a substantial good reputation.

In the extended model he specified the player types by each two sub-types (an implicit and an explicit one) (Table 2.1) and by the possibility that a player will change type over time. Originally defined for players of Multi-User-Dungeon (MUD), a multiplayer real-time virtual world, his framework is useful for various kinds of games.

Model of Skill Acquisition. Based on the model of skill acquisition [DD80, Dre04] people seek mastery in whatever they do (e.g. losing weight). The underlying assumption is, that by "acquiring a skill by means of instructions and experience" people "normally pass through five developmental stages" – novice, competence, proficiency, expertise and mastery [DD80, p. 0].

Cooperation and Competition. Intra-group solidarity (cooperation) and inter-group competition are two key aspects of human behavior [Jac05] and two basic mechanisms used in game design [PH12]. Whereas, in competition, “individuals or groups seek to outplay others in accordance with the game rules” [RUO+12, p. 7], cooperation encourages participation and collaboration; “the goal is not to win as a player but as a team of players” [SENAM+10, p. 253]. Both goal structures “can be widely implemented in a non-gaming context” [PH12, p. 2005]. Moreover, it is also possible to compete with oneself in order to become better now and in the future, compared to the past.

The high relevance of cooperation in motivating players has been demonstrated by Massive Multiplayer Online Role-Playing Games (MMORPG) [Yee06b] cooperative games [SENAM+10], and collaborative game-based learning [RUO+12]. An online survey related to player motivation provided data from 3,000 MMORPG players and identified teamwork as an important social component for player motivation [Yee06b]. Results of a background questionnaire showed that if they had to choose between cooperative and competitive games, 55% of the 60 6-16 years old kids preferred cooperative games, while 77% would have liked games with both elements [SENAM+10].

Learning. Learning, whether deliberately or inadvertently, is a key factor in behavior change. “In the social learning system, new patterns of behavior can be acquired through direct experience or by observing the behavior of others” [Ban77, p. 3].

Together with modeling our behavior on what others do, this is suggested by research to be a more promising way for achieving behavior change than raising awareness is [Jac05]. People learn most effectively from models who are seen as more successful by them [Ban77], attractive to them, influential to them or alike them [Jac05]. Collaborative game-based learning builds on social learning and is described as a game that "involves more than one player in gameplay with the pedagogical intention to promote co-operative learning between those engaged in the game." [RUO+12, p. 8]. Key factors for motivating collaborative learning are cooperation and a sense of belonging [RUO+12].

2.4 First Attempts to Introduce Gamification into the Field of Sustainable Consumption

Early approaches including gamification-based ideas have mostly been developed as prototypes with aspects from PT, eco-feedback technology, game design and other related fields. The dominating application domain for these systems is found in the home context, in particular with regard to domestic energy consumption. In the following, we introduce two examples of prototypes, which often are referred within literature and one example from the industry, all containing gamification-based aspects.

2.4.1 Domestic Energy Consumption

EcoIsland [TLS+09] is a "game-like application" addressing the final goal of reducing domestic energy consumption within a household. In regard to a target CO2 emission level, which is set by each family, rising energy consumption is correspondingly visualized on an IHD by a rising sea level eventually threatening a virtual island. Avatars representing the household members inhabit the island. Two possibilities for stopping the sea level from rising are provided; either through reduction of energy consumption or by acquiring emission rights. In order to reduce energy consumption, household members can select actions from a list of actions predefined by the system designer (such as turning down the air-conditioning). A lower sea level makes it possible to sell emission rights to other islands (neighboring households). The virtual earnings can be use to decorate the island. All neighbors are able to see all islands and all taken actions.

2.4.2 CO2 Emission Caused by Transportation

UbiGreen [FDK+09] is a mobile phone application which semi-automatically senses means of transportation and provides corresponding information on the behavior indicating CO2 emissions caused by taken choices. Small rewards are given to those who take "green" choices (e.g. taking public transportation, carpooling or walking). Feedback is provided over two different interfaces between which users can choose.

One shows a tree and the other a polar bear on a small iceberg. Both tree and iceberg indicate green choices. Progress is shown by a sequence of images. At the beginning the tree has no leaves and the iceberg, on which the polar bear is standing is very small. When green means of transportation are chosen, the tree gets more leaves and in the final stage bears apples. Correspondingly, the iceberg gets bigger and harbors more animals (fish, seals, other polar bears), finally the last picture shows northern lights above a large group of polar bears.

2.4.3 Eco-friendly Driving

Toyota built a special feature into their Prius line [Fog09], a miles-per-gallon meter, showing the average miles per gallon since the last fill-up. This feature is claimed to be the beginning of a trend called hypermiling [Quo10], a competition where car drivers try to drive as many miles as possible on one gallon. To do this they use different techniques, such as adjusting their driving style, driving behind trucks or driving when it's not windy.

2.5 Requirements for a Gamification-based Approach to Sustainable Consumption

By "[attempting] to harness the motivational power of games and apply it to real-world problems" [LH11, p. 1], gamification offers opportunities for overcoming limitations of PT in the domain of sustainable consumption.

Gamification by itself neither guides the designer through the identification of relevant game design elements nor teaches how to use, apply, and combine these elements (among themselves and within the context). "Yet despite the parallel increase in research on fun, entertainment, and motivation in video game play, we are still in want of theoretical models of the motivational pull of game elements" [Det11, p. 2].

In fact recent gamification-based approaches have been criticized for just randomly applying game elements, neither considering the application context nor the user's background. This is why they "will fail to drive participation and sustain user engagement" [KTCK12, p. 6]. Moreover, as pointed out in the previous section, current gamification-based approaches usually inherit some fundamental limitations of PT-based approaches.

We therefore define four requirements that can help constraining the search space for good design in the field of gamification-based approaches to sustainable consumption. This set of requirements is derived from the results and perspectives discussed in the preceding sections.

2.5.1 Requirement 1: Respecting Consumers as Individuals

Respecting consumers as individuals by enabling skill acquisition and multiple levels and types of challenges in order to provide multifaceted user experiences

The *model of skill acquisition* [DD80, Dre04] the *concept of flow* [Csi90] and the *framework of different player types* [Bar05] together, picture the dynamics and diversity of individual consumers. Put in simple terms, consumers include different player types who acquire different skills by different means. Consumers choose these means according to their desired level of challenge with the goal of maintaining themselves in the state of flow.

This dynamic is a driving force of engagement within individuals, and has to be taken into account by gamification-based approaches for sustainable consumption. Such an approach considers societal, cultural and demographic aspects (e.g., regulations, knowledge, restrictions, location of living, number of children, non- availability of alternatives...) influencing consumers' decisions.

This means that consumers should not be treated as users to be merely informed, but as social actors who are engaged in the process of sustainable consumption.

2.5.2 Requirement 2: Respecting the Consumers' Autonomy

Respecting the consumers' autonomy by designing game dynamics that authorize users to define their own sub-goals and the avenues for reaching their goals (e.g. according to time, place, action, device, brand)

Direct experience is one important factor in learning, which itself is a powerful factor in changing behaviors. Developing more sustainable behaviors with regard to consumption by allowing consumers to design their own routes and choose their own speed (e.g. by defining sub-goals) instead of following predefined paths and system structures, thus respecting consumers' autonomy, is an important part of gamification-based approaches for sustainable consumption.

This approach enables consumers to obtain experience alongside the core (offering an indirect path to sustainable consumption) and gives individual meaning to actions (and to their output). Moreover, consumers are part of the process of solution building. This is both a powerful motivational element and a bottom-up approach generating knowledge for the whole field of sustainable consumption.

2.5.3 Requirement 3: Introducing the Social Level

Enabling social interaction by providing possibilities for (normative) comparisons of individual achievements and the opportunity to share own experiences and suggestions with others in order to enable social learning

Gamification-based approaches to sustainable consumption only make sense when taken to the social level. By doing so, the isolated view of actions can be expanded by relating them to the context in which they are carried out.

This overcomes the rational approach of measurable aspects by adding meaning to specific actions. Normative comparisons expand multifaceted user experiences by introducing additional game elements, such as competition. Moreover, the sharing of suggestions and experiences might trigger more solutions and strategies for sustainable consumption and lead to spillover effects.

2.5.4 Requirement 4: Enabling Collective Action

Enabling group experiences by introducing game elements on a group level in order to expand user experiences and providing more possibilities for engagement, particularly intra-group cooperation and inter-group competition

This requirement differs from requirement 3 by specifically addressing the experience of collective action. By introducing the possibility of collective actions, gamification- based approaches enable the achievement of group goals. The combination with requirement 2, e.g. reaching group goals while setting individual sub-goals, widens the user experience and provides an additional motivational aspect. Moreover, by taking collective actions, synergetic effects become visual to individuals. This is relevant because single actions taken by individuals are often perceived as a drop in the ocean.

2.6 Conclusion and Future Work

We have discussed limitations of PT we consider relevant in the field of sustainable consumption, particularly

- the focus on measurable effects,
- the assumption of rational choice,
- an insufficient account of individual differences and social context,
- the paradigm of raising awareness and changing attitudes,
- the inherent technology paternalism.

Gamification-based solutions have great potential for engaging consumers in sustainable consumption, but are not per se immune to the limitations of PT. For this reason, a design framework for gamification-based solutions is needed.

Based on existing evidence from the literature in the fields of PT, eco-feedback technology, game design, psychology and related fields, we defined four basic design requirements for gamification-based approaches supporting sustainable consumption. The four basic design requirements are:

1. Respecting consumers as individuals
2. Respecting the consumers' autonomy
3. Introducing the social level
4. Enabling collective action

These requirements are intended to provide guidance to the designer who wants to go beyond the limitations of PT.

The definition of these basic requirements is a first stepping-stone toward a design framework for gamification-based approaches to sustainable consumption.

A complete framework will provide more guidance to the designer in selecting features depending on the application context, including cultural factors. Empirical research will be needed to develop aspects of such a design framework by developing and testing hypotheses about the effects of specific types of gamification on motivation in a sustainability context. The most central issue for a process that could be called "motivation design for sustainable consumption" is how to create a link between the physical and social reality. Sustainable consumption is rooted in physical reality, it is about using energy or buying material goods, while these actions are embedded in existing social practices.

Gamification adds a virtual world that creates a new link between the two spheres and supports the transformation of practices by using elements of games. Future research based on empirical studies will help to reveal the success factors of such an approach.

Chapter 3
Uncovering Sustainability Requirements

Original publication:
Uncovering Sustainability Requirements: An Exploratory Case Study in Canteens
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Abstract

Software systems are embedded into daily life and as such have significant effects on the behavior and decision making of both their users and the people affected by using these systems. Such effects can be positive or negative. Considering them in requirements engineering (RE) is an important step towards sustainable development, as RE strongly influences the development and the evolution of a software system. So far, RE researchers have focused on requirements about minimizing negative environmental effects. However, effects that are enabled by using a software system can also be positive. For example, a software system could motivate its users to take environment-friendly decisions. Corresponding requirements about such positive enabling effects have been far less addressed. In this paper, we present an exploratory case study where we elicited requirements about positive enabling effects with respect to environmental sustainability. The project we studied is about extending an existing decision support system for meal planning in canteens by game-based elements. The extended system shall motivate meal planners who work in canteens to make environment-friendly choices. Our contribution is an exemplar of concrete sustainability requirements as well as insight into the nature of sustainability requirements about positive effects that are enabled by the use of a software system.

3.1 Introduction

Any software system and its utilization have effects causing environmental impacts [Pen14],[MC12],[MHS11]. We categorize these effects into two groups. One group relates to the *direct effects* of *running* a software system, e.g., the energy and resources required for powering and cooling the computing equipment the system runs on or connects to. Such effects are usually considered to be negative with regard to sustainable development. The second group relates to *enabling effects*. These are effects that are enabled by *using* a software system. Enabling effects can be the result of automated processes and/or of human behavior that is influenced by using the software system. With regard to sustainable development, enabling effects can be both positive and negative[HA15]. For example, heating management software can reduce the energy consumption of a building significantly, which is positive. An e-commerce system providing business-to-consumer and consumer-to-consumer sales services may influence human behavior positively by encouraging people to sell used goods so that they get re-used, but it can also lead to over-consumption, which is negative. For a more detailed classification of effects of software systems on sustainability see Berkhout & Hertin [BH01] or Hilty & Aebischer [HA15].

Our dependency on software systems [JM13] and their ubiquity [PRRT14] within many societies has intensified the impact of enabling effects.

Consequently, when striving for sustainable development, we must take into account potential enabling effects when developing a software system, in order to avoid negative effects and leverage positive ones.

The importance of considering sustainable development in software engineering has been emphasized by researchers in the field [JM13, RR13a, AIMT11]. Due to its early influence in the development process of a software system, requirements engineering (RE) is considered to have the biggest impact on the eventual effects of a software system [RPTR14]. As such, RE provides promising opportunities to affect the transition towards sustainable development significantly [MC12, MHS11, RPTR14, JM13, RR13a].

Current RE contributions considering sustainable development have focused on minimizing negative environmental effects and referred to corresponding requirements as quality requirements, e.g. [MHS11, PRRT14, Pen14, RPTR14]. Sustainability requirements related to positive effects however, have not received much attention and can not be limited to quality aspects.

Our goal is to better understand sustainability requirements related to positive effects, specifically the ones that are enabled by end-users while using a software system. This paper describes an exploratory case study in which we elicit and discuss such sustainability requirements for a decision support system (DSS) that is extended with game-based elements for motivating meal planners to make choices that reduce the CO_2 value of their meals.

The contribution of our study is twofold. Firstly, we present an exemplar of concrete sustainability requirements related to positive enabling effects. Secondly, we discuss these sustainability requirements. The study reveals that when considering positive enabling effects (i) corresponding requirements include new requirements and existing requirements that become more important, and (ii) treating these requirements as quality requirements is inadequate as we found functional requirements and constraints. The study further provides some indication that (iii) corresponding requirements can be classified into requirements about *integration*, *(meaningful) representation*, and *(fair) comparison*, and that (iv) *indirect stakeholders* who are no system users, but are affected by the use of the system and influence its success, are important.

This paper is outlined as follows. We first provide background on the case study and related work on RE with regard to sustainable development. In Sect. III we describe our research approach, the study design and the research questions. The results and threats to validity are presented in Sect. IV, followed by a discussion in Sect. V and conclusion and future work in Sect. VI.

3.2 Background and Existing Work

In this section, we provide information about the case study as well as relevant background knowledge for readers less familiar with RE in the context of sustainable development. Further, we describe some earlier RE research which is relevant in the context of our study.

3.2.1 The Case Study

This case study is part of the project *CarbonFoodPrint*[1] initiated by Eaternity[2], a company that provides software-supported solutions helping people to make their own eating habits climate-friendly. In this project Eaternity collaborates with the Swiss branch of the Compass Group [3], a world-leading food service company.

The Current State. The process of planning meals that is applied within the Compass Group (Switzerland) consists of two phases: First, a small culinary development team in the headquarters composes and develops meal propositions for all canteens for the forthcoming months. Based on the categories offered in a canteen (e.g. meat, veggie, low carb) the proposed meals are accordingly filtered and sent over an SAP-based system to the canteens. In the second phase, the meal planners working in the canteens adapt the meals based on specific canteen-related criteria, (e.g., their budget and customers' preferences). A decision support system (DSS) is used to support the meal planners to plan meals by providing specific functions; in particular, the possibility of selecting ingredients (e.g., tomatoes), meal components (e.g., tomato sauce or spaghetti) and whole meals (e.g., spaghetti with tomato sauce) from a large recipe database, together with corresponding information on nutrition factors and costs.

[1] http://bit.ly/1L2Qzcc
[2] http://eaternity.com
[3] http://welcome.compass-group.ch/

The Project Context. The overall goal of the *CarbonFoodPrint* project is to motivate meal planners to select ingredients whose production and transportation emitted less CO_2 than possible alternatives. The project consists of two parts. The first part focuses on the calculation of CO_2 emissions by applying life-cycle assessment (LCA) [14006]. This is a specific technique to address the environmental aspects and potential environmental impacts such as use of resources and the environmental consequences of releases throughout a product's life cycle. The second part of the project focuses on the utilization and representation of these data to motivate the meal planners to select ingredients whose production and transportation have emitted less CO_2 than possible alternatives. To achieve this goal, the Compass Group (Switzerland) decided to order an extension of the existing DSS with game-based techniques for further processing the calculated LCA data and presenting them to the meal planners in a recurrent report.

The Context of our Case Study. The case study that we present in this paper contributes to the second part of the *CarbonFoodPrint* project. In the framework of a research collaboration with Eaternity and the Compass Group (Switzerland), the sustainability requirements for the new system were elicited and studied by the first author of this paper, together with a graduate student. As the focus on the CO_2 emission caused by the production and transportation of ingredients was given, our study is confined to sustainability requirements with respect to CO_2 which, actually, is only one aspect of sustainable development.

3.2.2 Requirements Engineering and Sustainability Requirements

Software systems are embedded in their environment which by nature is in a permanent process of change. As such, developing and evolving a sustainable software system is an ongoing process. Typically, the decisions that shape a software system are taken during RE [MHS11].

Sustainability. The term *sustainability* has been used in different contexts and overused for several purposes. To avoid any misunderstanding, we briefly define the terminology used in this paper. Based on the "Brundtland definition" [WD87], Christen proposes to conceptualize sustainability as an "attempt to grant the right to a decent life to *all living human beings* without jeopardizing the opportunity to live decently in future" ([Chr10, p.2]). As such he emphasizes that sustainability does not solely focus on future generations, but also on human beings living now. He also argues that sustainability is not limited to sustaining aspects, but also addresses enabling aspects. By definition, sustainability is a global (temporal and spatial) concept which makes it clear that no single technology can be sustainable in this sense. However, technology can support the transition towards sustainable development [HA15]. Based on this notion of sustainability we define the following terms.

- A *sustainable software system* is a software system that supports the transition towards sustainable development.
- A *sustainability requirement* is a requirement for a sustainable software system which concerns sustainability.
- A *positive enabling effect* is an effect that is enabled by using a software system and positively contributes to the transition towards sustainable development.

Different metaphorical descriptions of the roles of *environment*, *society*, and *economy* in sustainable development exist. As the economic system is part of human society, which in turn is part of the environment, we use the metaphor of nested circles, where economy is represented by the inner circle, society by the middle one and environment by the outer one. For more information see for example Hilty & Aebischer [HA15].

State of Research. The high importance of addressing the concept of sustainable development within the process of requirements elicitation has been recognized by the RE community, e.g., [JM13, RR13a, AIMT11]. However, as noted by Becker [Bec14], this has not yet been transferred into practice successfully. Prior RE research has mainly conceptualized sustainability requirements as quality requirements (i.e., a sub-category of specific quality requirements in the taxonomy introduced by Glinz [Gli07].

Thereby, the focus was on goal modeling processes e.g. by regarding sustainability as a trade-off between business goals [CEH+09], by using the idea of generic goal refinement as a checklist for sustainability requirements [MHS11], by treating them similarly to conflicting goals of budget restrictions and quality improvements [PF13], by suggestion how to align the objective of environmental sustainability with the other objectives [Pen14], and by building upon different levels of impacts [BNDS14]. Further, Roher & Richardson work on patterns for sustainability requirements [RR13b].

3.2.3 Sustainability Requirements Related to Enabling Effects

Most existing work on sustainability requirmements as described above focus on direct effects (cf. the classification presented in the introduction) and treat sustainability requirements as goals or as specific quality requirements. Sustainability requirements related to enabling effects of a software system are far less addressed both in research and – to our experience – also in industry. A possible explanation is that in most cases direct effects are directly connected to economic goals, whereas for enabling effects, such a relation is hard to establish in most cases.

Nevertheless, as outlined by Wang [Wan15], research shows that while considerations about sustainable development are becoming more relevant in societies, positive environmental effects positively impact the value chain and the image of a company. Consequently, requirements related to enabling effects of software systems increasingly gain relevance for both companies and their stakeholders.

3.3 Research Methodology and Study Design

For choosing our research methodology, we considered the following facts: (i) We wanted to analyze and better understand sustainability requirements with respect to positive enabling effects, (ii) there is little knowledge available about this kind of requirements, (iii) we had the opportunity to study a real industrial project in this context. Given this situation, we chose an exploratory case study as our research methodology. Such a study enables an in-depth investigation of a phenomenon in its context [BGM87] and is specifically suitable when little knowledge about the subject is available [SOR13]. Further, the results of an exploratory study form the basis for both theory generation [BGM87] and constructive solution design.

3.3.1 Research Goal and Research Questions

According to our research plan and the given project context, we formulated our research goal as follows.

Goal. Analyze *sustainability requirements* for the purpose of *developing sustainable software systems* with respect to *positive enabling effects* from the viewpoint of *the end-users* in the context of a project for extending an existing software system with game-based mechanics.

Research Questions. From this goal we derived two research questions:

RQ1: What is specific about requirements concerning positive enabling effects?

RQ2: How can game-based mechanics motivate positive enabling effects when extending existing software systems?

3.3.2 Study Design

We followed a "mixed methods" approach [ESSD08], consisting of three sequential steps: a *contextual inquiry*, *semi-structured interviews* and an *online questionnaire*. We used this approach for investigating our research questions from more than one perspective, thus getting more thorough results. As mentioned in Sect. II.A, the tasks of eliciting the requirements and conducting the study were both performed by the first author of this paper, together with a graduate student.

Study Setup. The process for all three steps and the questions to be asked were elaborated by the first author of this paper with support from the graduate student, then reviewed by a group of RE researchers and finally improved according to the feedback received. The interviews and the questionnaire were both piloted with people neither specifically related to the domain of RE nor to the one of sustainability.

This approach was chosen to make sure the questions are clear to participants who are unfamiliar with these domains [KP08].

The study was carried out over a period of four months and included eight steps: (1) Preparing the contextual inquiry, (2) carrying out the contextual inquiry and evaluating the results, (3) designing the interview questions, (4) conducting pilot interviews, (5) carrying out the interviews and evaluating the results, (6) designing the questions following the guidelines for creating a questionnaire by Kitchenham & Pfleeger [KP08], (7) publishing the questionnaire, (8) evaluating the questionnaire results. Note that the results of the pilot interviews were not included in the data analysis.

All steps of the study were conducted in German. Consequently, the questions and interviewee quotes reported in this paper are our translations of the German originals.

Selection of Participants. The Compass Group (Switzerland) selected the participants for the contextual inquiry and the interviews. However, we could provide our criteria for the selection process. The following of our criteria were accepted and applied by the company: (1) all participants are responsible for the meal planning process and as such are direct end-users of the DSS; (2) the contextual inquiriy is conducted in two sessions, one in the headquarters of the company and one in a canteen; (3) at least 15 meal planners are selected for the interviews; (4) the group of participants is heterogeneous with regard to canteen size, region, and work sector ("Business & Industry" (B&I) and "Eductation" (Edu)).

We did not include gender, age or nationality into our selection criteria, since we considered them as irrelevant for the purpose of the study. Eventually, 19 meal planners working in different canteens participated in the semi-structured interviews.

The URL of the online questionnaire was sent to all meal planners (about 150). 67 participants finished the online questionnaire. However, seven of them did not answer the question about current reasons for changing ingredients. *The questionnaire results presented here come from the 60 meal planners who answered all questions (this includes all participants of the interviews and the contextual inquiry).*

Contextual Inquiry. To understand the current situation, i.e., how meal planners currently work and apply the existing DSS, we conducted a contextual inquiry in two sessions: the first one at the headquarters of the Compass Group (Switzerland) and the second one in one of the canteens. Contextual inquiry [BH98] is an elicitation technique that studies stakeholders in the field, bringing the requirements engineer in contact with the stakeholders in their real work environment. Thereby, the requirements engineer takes a role similar to the one of an apprentice, asking questions while observing the work process. By allowing requirements engineers and stakeholder representatives to work together and to share insights, a contextual inquiry enables a full understanding of the work practices in the specific work environment. As a contextual inquiry is exploratory and open-ended, we did not prepare questions beforehand, with the exception of some ice-breaking questions for starting the inquiry sessions.

Semi-Structured Interviews. The questions for the interviews were grouped into three parts: *demographics and current work routines*, *usability*, and *motivation*. While the questions about the first two parts build on the results of the contextual inquiry, the ones about motivation regarding the game-based aspects refer to the results from our previous research on requirements for game-based approaches motivating sustainable consumption [HH15]. Four representative interview questions are given in Table 3.1. IQ-1 is from part one about current work routines, IQ-2 is from part two about usability, and IQ-3 as well as I-Q4 are from part three about motivation, however, I-Q4 also affects part two. The full set of interview questions (in German) is available at [4].

The interviews lasted between 25 and 45 minutes on average. The time difference can be explained by our approach of conducting semi-structured interviews with a mix of open-ended and specific questions. We did this for enabling the elicitation of both foreseen and unexpected information [Sea99]. This was specifically relevant since the domain knowledge of favorabale enabling effects is still immature in RE. It also helped to build a positive rapport with the interviewees [SSL08].

All interviews were conducted over Skype by calling the interviewees on their business phones. This approach was chosen because the interviewees were distributed over the whole country. So visiting them all would have been too costly and also not possible in the timeframe given for the interviews.

[4] http://bit.ly/1QyuR3i

Half of all interviews were conducted by the first author of this paper, the other half by her graduate student. To align the interview styles and reduce observer bias, the first two interviews were conducted jointly by the first author and her student and then discussed between them in a retrospection session. As mentioned above, the interview questions as well as the interviews were piloted before conducting the actual interviews.

Online Questionnaire. We used the results from the interviews as a basis for designing the online questionnaire. Our goal was to elicit quantitative information about important aspects of sustainability requirements from a sample of involved people which is larger than the number of meal planners interviewed. We exploited the majority of the interview questions in the online questionnaire, omitting the ones that focus on the end-user's attitude towards the project. Table 3.1 shows four representative questions (QQ-1–QQ-4) that we further analyze in this study. Semantic differential scales [OST64] were applied to evaluate the participants' attitude. This type of scale is similar to the Likert scale [Lik74] with the benefit of revealing both the direction and the intensity of each opinion. For questions about familiar topics we used an even scale (four point), for questions where we expected less or non-familiarity, we used an odd scale (three or five point, including a neutral point). This approach is generally suggested for defining the number of alternatives given in ordinal scales [CI80]. The link to the questionnaire was published over the intranet of the Compass Group (Switzerland) together with background information about the project, who we are, the goal of the study and criteria for participation.

Table 3.1: Interview Questions (IQ-) and Questionnaire Questions (QQ-)

Identifier	Original Question Id[1]	Question (English translation)
IQ-1	2.d	According to what criteria do you compose a meal?
IQ-2	3.a	Can you imagine that the idea of reducing the CO_2 value of meals due to the choice of ingredients is realizable in your canteen?
IQ-3	4.a	Are you additionally to the CO_2 value interested in the following information? i.What the CO_2 value means e.g. how many kilometers driven by car do correspond to it? i.1 Are you further interested in other representations? If so in which?
IQ-4	6	Do you believe that the CO_2 values of different canteens can be compared with each other in such a report?
QQ-1	4.1.1	What does motivate you to change a meal? Formulated in a clearer way, how strong does one of your changes affecting a meal component or ingredient depend on the following criteria? (costs, variety, customer preference, season, compliance, environmental aspects)
QQ-2	5.3	How should the CO_2 emission value of your meals additionally be represented in order to raise your interest? (number of kilometers a mean of transportation has to make; amount of energy an ordinary private household has to use; number of days an ordinary private household has to be heated in order to emit the same amount of CO_2; number of trees that are needed to compensate the same amount of CO_2);
QQ-3	7.1.1	How good do you think is the following information? Segmentation of the CO_2 based on the process steps; meal components; origin of ingredients
QQ-4	6.1	How strong have the following factors to be considered in order you perceive the comparison of the CO_2 emission of different canteens to be fair? (size of the canteen according to the number of cooked meals; the number of employees working in the kitchen; the number of meal categories served in a canteen; the customer preferences)

"IQ" refers to the interview questions and "QQ" to the questionnaire questions.
The column "Original Question Id" refers to the corresponding original question id of the interview or the questionnaire, available under[1]: http://www.ifi.uzh.ch/rerg/research/stakeholderengagement/garuso

Technically, we used an online questionnaire tool[5] for creating the questionnaire. The full set of questionnaire questions (in German) and the questionnaire design are available at [6].

3.3.3 Collecting the Data

Data collection started in July 2014 with the two contextual inquiry sessions and ended in October 2014 when the online questionnaire was online for two weeks.

The full data set has a size of 81, comprising the data from two contextual inquiry sessions, 19 interviews and 60 fully completed questionnaires. It turned out that the first contextual inquiry session had primarily served for making the researchers familiar with the context of the project, so we excluded it from the data set. Further, one interview was not recorded due to a technical problem which we realized only after the interview was finished. Hence, we also excluded that interview from the data set. All interviewees as well as the participant of the contextual inquiry also answered the questions in the online questionnaire. So we have a total of 79 data points from a total of 60 participants for analysis. With respect to the canteen sectors, i.e., Business & Industry (B&I) vs. Education (Edu), the data are distributed as follows: (i) contextual inquiry session: zero B&I, one Edu; (ii) interviews: fourteen B&I, four Edu; (iii) online questionnaire: fifty B&I, ten Edu.

[5] http://ww3.unipark.de
[6] http://bit.ly/1FiFKdO

Table 3.2: Overview of all participants whose data was evaluated

Attributes / Domain	Business & Industry	Education
Percentage of all participants	83%	17%
Average # of years in position	7	5
Median # of years in position	5	3
Average # of meal categories	3	4
$<$ 150 meals/day	42%	20%
150-499 meals/day	42%	40%
500-1999 meals/day	16%	40%

3.3.4 Participant Demographics

Some demographic information about the participants is summarized in Table 3.2. 83% of all participants work in B&I canteens and 17% in Edu canteens. On average, the participants have more than five years experience in their position. Regarding meal variety and number, participants working in B&I canteens have three meal categories on average (e.g., meal with meat, vegetarian, low-carb), while participants working in Edu canteens have four. Around 40% of all participants from both sectors work in canteens that produce between 150 and 499 meals per day. 42% of the B&I canteens and 20% of the Edu canteens produce less than 150 meals per day, and more than 500 meals are daily produced in 16% of the B&I canteens and in 40% of the Edu canteens.

3.3.5 Analyzing the Data

All data is exploratory, which means we did not pre-specify a hypothesis as it is done in a confirmatory analysis. The end-product of exploratory data analysis is rather suggesting patterns for further studies and providing hypothetical insight into these patterns instead of statistical figures [Yu94]. As such we did not apply any statistical tests, but provide first insights into sustainability requirements for positive enabling effects with regard to sustainable development.

Contextual Inquiry. Information from the contextual inquiry sessions was first structured to identify main work processes which then were used for defining the interview questions. In the presentation of the results in the next section, the data from the contextual inquiry is not analyzed separately, but presented together with the data from the interviews.

Semi-Structured Interviews. To be able to better evaluate the data from the interviews we structured the data by first transcribing and then coding them according to the process described by Seaman [Sea08]. The corresponding codes are listed in Table 3.3. The results of this analysis were used to define the questions and structure of the online questionnaire.

Online Questionnaire. As it is common in exploratory studies, we visually analyzed the quantitative data from the questionnaires, choosing divergent stacked bar charts.

Table 3.3: Overview of Interview Results

Codes Used to Quantify the Qualitative Results (Semantic:[effect_causedBy_inSystem])	**Frequency** Number	Percent	**Origin** IQ	Spont.
changeIngredients_customers_current	13	72	✓	
changeIngredients_costs_current	12	67	✓	
changeIngredients_variety_current	6	33	✓	
successCO_2Red_changingIngredients_new	13	72	✓	
constraintCO_2Red_costs_new	9	50		✓
constraintCO_2Red_customers_new	9	50		✓
constraintCO_2Red_space_new	2	11		✓
successCO_2Red_integratedInWorkProcess_new	13	72		✓
successCO_2Red_alternativesShown_new	6	33		✓
successCO_2Red_CO_2Rep_new	17	94	✓	
successCO_2Red_CO_2RepGraphically_new	5	28		✓
successCO_2Red_CO_2PerOrigin_new	2	11		✓
successCO_2Red_CO_2PerProcessSteps_new	3	17		✓
successCO_2Red_CO_2PerComponents_new	4	22		✓
comparisonCO_2Possible_gamification_new	13	72	✓	
comparisonCO_2Possible_numberOfMeals_new	8	44		✓

The codes are presented in the order that they appear in the paper; the upper group is referred to in Sect. IV.A, the lower one in Sect. IV.B. “Red” stands for “Reduction”, “Rep” for “Represented”. In column “Origin”, “IQ” indicates codes that stem from explicitly asked interview questions, while “Spont” indicates codes found in information spontaneously raised by interviewees.

3.4 Results

In this section we present our results. As usual when presenting qualitative results, the data are complemented with quotations from the interviewees. The quotations are written in italic, the interviewee who stated the quote is indicated in brackets by "I-" followed by the number of the interview. We coded relevant information in the qualitative results to structure and quantify them; these codes are underlined and in brackets. Table 3.3 lists the sixteen codes that we used, together with the frequency of their appearance in the interviews.

The questionnaire results for QQ-1–QQ-4 (cf. Table 3.1) are visualized in Figures 3.1-3.4 in the same order as the corresponding questions.

We present the results grouped by topics. Within each topic, we first present the results from the interviews regarding this topic, and then the corresponding results from the online questionnaire.

3.4.1 Requirements Looked through the Sustainability Lens

The first aspect we investigated was whether and how the current set of requirements changes from the end-users' perspective when adding the dimension of sustainable development to the domain context (RQ1). We first focused on actually existing requirements causing the participants to change ingredients in their current work process. Second, we elicited requirements that the participants perceive as important if they had to select ingredients with respect to CO_2 emission. This subsection highlights the aggregated results related to this aspect.

Current Requirements Motivating Change. We specifically asked the interviewees about reasons for changing ingredients in the proposed meals they get from the culinary development team (IQ-1). The three criteria mostly mentioned are *customers' preferences*, *costs* and *variety*.

As indicated in Table 3.3 for thirteen interviewees customers' preferences (changeIngredients_customers_current) are a strong reason to change ingredients, twelve emphasized the relevance of cost restrictions (changeIngredients_costs_current) and six mentioned the variety (changeIngredients_variety_current) of their meals as an important reason. Interviewee I-8, for example, highlighted both variety and customers' preferences: *"I do it according to the following criteria, such that there is variety. Theoretically, pork is the cheapest meat we can get, but I nevertheless look that it is only served once a week. Also a little bit because of our Muslims (...)"*.

In the online questionnaire, we further explored these results by asking the participants to rate the importance of *costs*, *variety*, *customers' preferences*, together with *the seasons*, *compliance with suppliers*, and *the environment* as a reason for them to change the ingredients (QQ-1). Participants could rate the importance on a semantic differential scale of four criteria: "Plays no role at all", "Plays a minor role", "Certainly plays a role", "This criterion is one of the most important reasons for change". The results shown in Fig. 3.1 support what we found in the interviews: *Customers' preferences* and *costs* are the two most important reasons to change ingredients in both Edu and B&I canteens. *Variety* and *season* come next. Participants working in Edu canteens rate these two criteria as equally important, while participants working in B&I canteens rate *season* to be slightly more important than *variety*.

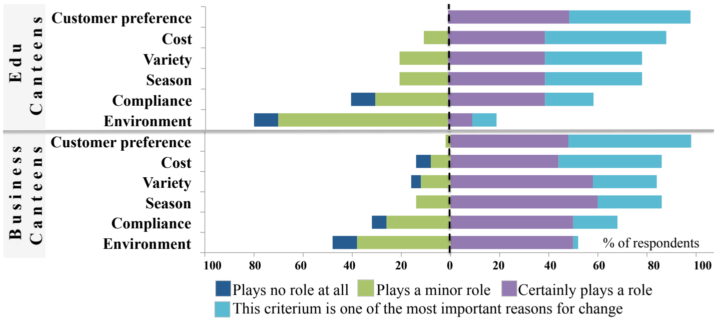


Figure 3.1: Evaluation of reasons to change ingredients in the current work process

Considering Sustainability Requirements. When asked the interviewees whether they can imagine reducing the CO_2 emission of their meals by selecting specific ingredients (IQ-2), thirteen were positive about having the potential to do so (successCO$_2$Red_changingIngredients_new) . However, the interviewees agreed that this goal is only achievable when considering certain constraints. The results described below show that (i) *costs* and *customers' preferences* are perceived as the two most relevant constraints if the context of sustainable development is added; (ii) the influence of these two constraints becomes stronger in this context and new constraints become relevant; (iii) an integration of the game-based extension into the existing DSS is important.

Cost constraints (constraintCO$_2$Red_costs_new) were stated by nine interviewees to challenge the successful consideration of CO_2 emission when selecting ingredients. Three of them regard cost restrictions as a major criteria for a project failure.

The rest of them is not that strict, however they mentioned that local and organic products usually are more expensive than non-organic products or products from farther away. They highlighted that if their budget remains the same, customers had to pay the cost difference. Interviewee I-17 considered the relevance of a company-wide change: *"Well it [the success] depends on what kind of food it is. In my opinion, if costs raise, we have to pass these costs on to our customers in order to stay in the green zone [with the costs]. (...) Actually, the whole company should have to participate."*. I-14 stated: *"(...) We have to get the cheapest products in order to fulfill the terms of the company and meet the demands of the customers (...) the customers have to rethink because, if I buy a regional product, this has immediate influence on my costs. "*.

Customers' preferences are further regarded as a constraint that challenges the success of the project (constraintCO_2Red_customers_new) by nine interviewees. Seven of them can imagine to possibly manage this challenge by involving the customers (e.g., by explaining the effects). The other two do not think that customers will change their eating habits or pay more for climate-friendly food. I-14 stated for example: *"Well, the cooks would like to consider this [the CO_2 emission related to the ingredients]. It has been a nonsense to offer tomatoes in December. However, it is a fact that not us, but the customers do rule the market (...) In my opinion the awareness of the customers is not yet there."*

The size of the work space was highlighted by two interviewees (constraintCO_2Red_space_new) as a major constraint. Little space in the kitchen affects work processes and as such the choice of ingredients. I-12 put it this way: *"Our restaurants are not all equipped in the same way (...) Some [of us] really must additionally plan their meals based on the available space [to process the food] and the storage possibilities and then decide whether they buy fresh broccoli or frozen broccoli."*

The proper integration (successCO_2Red_integratedIn- WorkProcess_new) of the game-based extension in the existing DSS is regarded as highly important by thirteen interviewees. For example, six of them said that it is highly important to have immediate access to alternative ingredients with a lower CO_2 emission value while planning meals over the system (successCO_2Red_alternativesShown_new). I-2 emphasized: *"(...) there really must be alternatives with which the CO_2 emission value can be reduced. Showing a direct alternative in the sense of 'tomatoes from Italy instead of cherry tomatoes from overseas' should be possible."* In this context, I-7 highlighted time pressure as a reason: *"When we get the [suggested] meal plan, it [the system] has to be ready with the CO_2 emission values. Because we cannot search extensively for this information on the lists of the vegetable, meat, or fish suppliers (...) this [information] has to be integrated and then we can work."*

3.4.2 Game-based Mechanics for Positive Enabling Effects

The second aspect we investigated was about how game-based mechanics have to be applied to motivate positive enabling effects in the given context (RQ2). Our focus was on a meaningful representation of the CO_2 emission value and on relevant factors for comparing the values of different canteens with each other. In this sub-section we present the aggregated results.

We asked the interviewees if the CO_2 emission shall be represented (successCO$_2$Red_CO$_2$Rep_new) by more familiar measures (IQ-3) and provided the number of kilometers driven (i.e., how many kilometers one could drive for emitting the same amount of CO_2) as an example. Seventeen interviewees agreed on the importance of a meaningful representation. I-12 added that such a value would even be more meaningful if represented by a journey. *"It would be good if you could say, we have saved that amount of CO_2, this is enough to travel from here to Moscow or simply, you could travel that far with this amount (...) because we do not know what consumes how much [CO_2]. For example, when I drive home with my car, I know I produce CO_2, but I do not know how much. And this is the reason why we don't know what is a good value and what is a bad one."* Five interviewees highlighted the relevance of using graphics and pictures (successCO$_2$Red_CO$_2$RepGraphically_new) . I-14 explained it this way, *"(...) something like '[with this amount of CO_2] you could have driven from here to there with a truck' and then showing something similar to Google maps. This way, it becomes visible right away that I could have driven to Marseilles."*

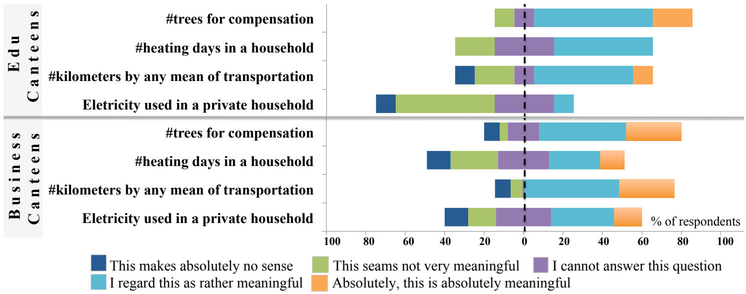


Figure 3.2: Evaluation of alternatives for representing the CO_2 value

The questionnaire results underline these results. Together with the given example on the amount of kilometers we provided three more representation options to rate for (QQ-2): the *number of trees needed to compensate the amount of* CO_2 *emitted*, the *used heating energy*, and the *used electricity* in an average household (Fig. 3.2). These four options could be rated on a semantic differential scale of 5 criteria: "This makes absolutely no sense", "This seams not very meaningful", "I can't answer this question", "I regard this as rather meaningful", and "Absolutely, I think this is absolutely meaningful". The results show that the number of trees needed for compensation and the number of kilometers that can be driven are similarly perceived as highly meaningful for representing the amount of CO_2 emissions. Participants from both sectors were much less interested in a representation by the energy consumption in a household of both electricity and heating.

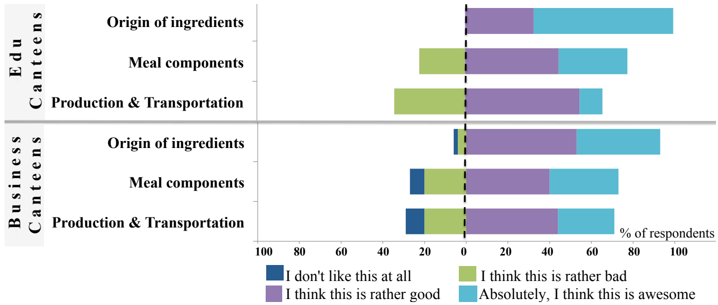


Figure 3.3: Evaluation of segmentation factors

Segmentation of the CO_2 value was raised by four interviewees. Two of them wanted a segmentation based on the origin of ingredients (successCO2Red_CO2PerOrigin_new) e.g., the CO_2 value of a tomato from Greece compared to one from Italy. Three interviewees were interested in segmenting the CO_2 value according to the two process steps of production and transportation (successCO2Red_CO2PerProcessSteps_new) , and all four found it relevant to segment the meals with regard to their components (successCO2Red_CO2PerComponents_new) , e.g., the two components pasta and pasta sauce. I-14 made this very clear: *"When you do something like this [the project as a whole], I think it is good that we have a learning effect, something like 'Ahaaaaaa, there it is, this shrimp has messed up our whole meal statistics (...) This way rethinking happens. We are a bit practice-oriented."*

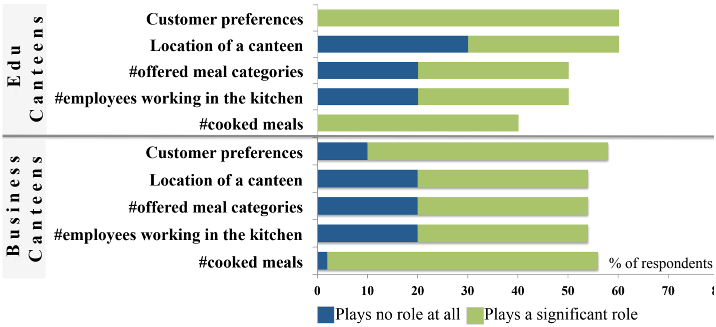


Figure 3.4: Importance of different factors regarding comparison

These results were exploited further in the questionnaire by asking to rate the segmentation factors *origin*, *meal components*, and *process steps* (QQ-3) on a semantic differential scale of four criteria: "I don't like this at all", "I think this is rather bad", "I think this is rather good", "Absolutely, I think this is awesome". The results show that the majority of both sectors is interested in comparing ingredients based on their origin (Fig. 3.3).

As game-based techniques typically involve comparisons, we specifically asked whether the CO_2 value of different canteens can be compared with each other (IQ-4); thirteen interviewees said yes (comparisonCO_2Possible_gamification_new) . Eight of them stated that the most important condition to consider for enabling comparisons between canteens is the number of meals produced (comparisonCO_2Possible_numberOfMeals_new) .

I-17 got very specific: *"You cannot compare a small canteen with a large one (...) If I compare two small canteens with each other that sell on average approximately sixty to eighty meals per day, then I think this is comparable. (...) I think here we should differentiate such that we only compare very similar canteens, also with respect to the location."*

These interview results are supported by the results from the questionnaire (Fig. 3.4). The participants could rate the importance of *number of meals*, *of employees working in the kitchen*, *of meal categories offered*, *location of the canteen*, *customers' preferences* for comparison (QQ-4), on a semantic differential scale of four with the two opposite criteria: "Plays no role at all" and "Plays a significant role". The majority of participants from B&I canteens selected the number of meals, followed by customers' preferences to enable fair comparison, while the majority of participants form Edu canteens selected customers' preference as the top criterion, followed by the number of meals.

3.4.3 Threats to Validity

We discuss the threats to validity using the usual four categories: internal, external, construct, and conclusion validity [WRH$^+$12].

Internal Validity reflects the relationship between cause and effect. The internal validity of our study is limited due to its very nature: in an exploratory case study in a real world project, many potentially confounding factors cannot be controlled.

A potential threat is the fact that the persons participating in the contextual inquiry as well as the interviewees were selected by the Compass Group (Switzerland). We do not consider this a major threat because we provided the company with our selection criteria and also did not find any evidence for selection bias when analyzing the interviews. Answering the online questionnaire was voluntary, which may cause the results to be biased due to highly supportive or highly non-supportive participants. Since the subject of the study was equally interesting for both supporters and opponents, we do not believe that the outcome of our study is affected by this potential threat. We mitigated potential maturation problems by scheduling the interviews during working hours and limiting their duration to 20-40 minutes.

External Validity refers to the extent of being able to generalize the results. The biggest limitation to the external validity of our study is the fact that (i) the study was conducted in a single company and (ii) the project was limited to positive enabling effects with respect to CO_2 emission. However, the setting of our study is typical for systems in the service domain: employees of a service company use a software-based system as end-users to provide services to the customers of the company, while the customers' preferences as well as cost considerations have a major influence on the system's requirements. Further, reducing CO_2 emission is a problem that, in our opinion, can be considered to be representative for the whole domain of problems considering sustainable development.

Based on these two reasons, we argue that our results are generalizable at least to some extent to positive enabling effects about sustainability in general for systems in the service domain.

Construct Validity describes our ability to measure what we actually intend to measure. All participants had the same tasks. However, we believe to have reduced mono-operation bias by including different work locations and work domains (Business & Industry, Education) into our study. We have minimized mono-method bias by using methodological triangulation (contextual inquiry, interview, questionnaire). To avoid evaluation stress, we assured all participants that their data were treated confidentially and evaluated for research purposes only.

Conclusion Validity is concerned with drawing correct conclusions based on our observations. The first author was involved in designing the study and executing the elicitation techniques, which could potentially cause observer bias. For mitigating this threat, we used methodological and observer triangulation and reviewed the structure and questions of all three elicitation methods with a group of experienced RE researchers. By conducting several pilot studies we strengthened the quality of our wording. Further, we encouraged the interviewees to ask for clarification if something was unclear. Therefore, we do not consider measure reliability as a major threat.

3.5 Discussion

In this section, we discuss the results of our study with respect to our two research questions and present some key findings.

3.5.1 RQ1: What is specific about requirements concerning positive enabling effects?

The results of our study show that the requirements do change when sustainability comes into play. In our study, when extending the existing DSS for meal planning with game-based mechanics for motivating environment-friendly choices to achieve a reduction of CO_2 emissions, we mainly found three kinds of changes in requirements: new constraints, existing constraints that become more important, and new functional requirements.

For example, the size of the kitchen is a new constraint that the interviewees only perceive when the system is used in the context of positive enabling effects for achieving a reduction of CO_2 emission. The smaller the kitchen, the less fresh food can be processed, which means that the meal planners have to go for more frozen or pre-processed food. This, in turn, has an effect on the CO_2 footprint of the meals.

Participants from both Edu and B&I canteens identified *customer preferences* and *cost restrictions* as the most important constraints.

The interviewees emphasized their fear about increased cost constraints in the context of positive enabling effects due to higher prices for local and organic food. Further, they are afraid of loosing customers by excluding off-season products, which results in a smaller variety of food. That means that the existing constraints of *customer preferences* and *cost restrictions* become more important in a sustainability context.

72 percent of all interviewees emphasize the need to integrate the information about CO_2 emission values into the DSS. 33 percent specifically want to be able to immediately access a list of alternative ingredients with respect to their CO_2 footprint. These are new functional requirements.

Consequently, treating sustainability requirements as a sub-category of specific quality requirements (cf. Section 3.2.2) turns out to be inadequate. Requirements concerning positive enabling effects can be functional requirements or constraints.

The growing importance of customer issues in the context of positive enabling effects such as *customer preferences* and *cost restrictions* also provides evidence that in the context of sustainability requirements, there is a strong need for taking into account also the indirect stakeholders of a system (i.e., those who are not end-users of the system, but are affected by its use, e.g., customers).

3.5.2 RQ2: How can game-based mechanics motivate positive enabling effects when extending existing software systems?

The results show that it is important to integrate the game-based mechanics directly into the underlying system and that end-users have to perceive the representations of sustainability goals to be meaningful as well as comparisons to be fair.

As mentioned above, the interviewees emphasize the need to integrate the information about CO_2 emission values into the DSS and want to be able to immediately access a list of alternative ingredients with respect to their CO_2 footprint.

The requirement of representing the CO_2 values in a meaningful way is perceived as relevant by 94% of all interviewees. Metaphorical representations such as *number of trees needed to compensate the CO_2 emission* or *number of kilometers made by a mean of transportation until the same amount of CO_2 is emitted* are preferred over more abstract representations such as energy equivalents. Interviewees also mentioned the importance of concrete and visual representations e.g a concrete example for a trip from city A to city B, preferably indicated on a map. A proper segmentation of the displayed information is also important. In our study, most participants favored the origin of ingredients as segmentation criterion.

As discussed in our previous research [HH15], comparison of individual achievements is an important game mechanic for motivating sustainable actions. The results of our study underline the importance of considering the work context to enable fair comparison when comparing the CO_2 footprint of different canteens with each other. The relevance of *customer preferences* as a factor for enabling fair comparison again underlines the need for taking the needs of indirect stakeholders into account.

When analyzing the interview data with respect to the codes that originate from information provided spontaneously by the interviewees (see Table 3.3), we found that this information (and hence, the corresponding sustainability requirements) can be grouped into three categories: (a) integration of sustainability information into the current system and work process (i.e., by properly extending the current software system instead of just adding a new, separate module), (b) meaningful representation of the addressed sustainability aspect (CO_2 emission in our study), and (c) fair comparison of the achievements of the addressed users (meal planners in different canteens in our study). Although more research is necessary to establish the generalizability of this finding, our study provides some evidence that a classification of sustainability requirements with respect to positive enabling effects into the classes *integration*, *(meaningful) representation* and *(fair) comparison* makes sense.

3.5.3 Key Findings

In summary, we draw five key findings about sustainability requirements regarding favorable enabling effects from the results of our study. In the context of positive enabling effects regarding sustainable development:

- Requirements for a software system do change when sustainable development is considered.
- We find both new requirements and existing requirements that become more important.
- Considering sustainability requirements to be a subset of quality requirements is inadequate. We also found functional requirements and constraints.
- Game-based mechanics need to be integrated directly into the underlying system.
- Meaningful representations of the sustainability aspect as well as fair comparison are important.

Further we have two findings where our study provides some evidence, but further research is necessary.

- Sustainability requirements can be classified into three classes: *integration*, *(meaningful) representation* and *(fair) comparison.*
- Indirect stakeholders, i.e., those affected by the use of the deployed system, should be involved when eliciting sustainability requirements.

3.6 Conclusion and Future Work

We reported on the results of elicited sustainability requirements regarding positive enabling effects. The study includes 78 data points from 60 participants working in 60 different canteens. Our main contribution is to reveal differences of such sustainability requirements compared to requirements in traditional settings, as well as important requirements to consider in a context of sustainability requirements for favorable enabling effects. Moreover, we found evidence that indirect stakeholders are important in this context and a possible classification of sustainability requirements.

In our future work we will further exploit the findings of this study. In particular, we plan to investigate the elicitation of sustainability requirements from indirect stakeholders who are outside of organizational reach.

Chapter 4
A Stakeholder-centric Motivation Concept

Original publication:
Tailoring Gamification to Requirements Elicitation: A Stakeholder Centric Motivation Concept
M.Z. Huber and M. Glinz
10th International Workshop on Cooperative and Human Aspects of Software Engineering

Abstract

Involving stakeholders in requirements elicitation is a cornerstone of successful requirements engineering (RE). With the recent technological advances, the number of stakeholders of a system has significantly increased. Major stakeholders, end-users in particular, are increasingly difficult to reach, because they may be globally *distributed and outside organizational reach, i.e., they are no members of the organizations that are involved in the development of a system. Online elicitation platforms allow to elicit requirements collaboratively from a large number of distributed stakeholders. However, such platforms are not sufficient for motivating stakeholders outside organizational reach to contribute voluntarily. Gamification is a potential means for creating and sustaining such motivation. However, there is little research on stakeholder engagement with gamification so far. Current approaches particularly do not consider that stakeholders learn during elicitation and that their motivational factors also change. In this paper, we address this gap with a motivation concept that is inspired by the theories of experiential learning and need satisfaction. Our contribution is threefold. First, we suggest how to characterize these stakeholders despite not knowing who they are. Second, we show the role of experiential learning and need satisfaction with respect to gamification in the context of requirements elicitation. Third, we present a three-dimensional concept of how to motivate these stakeholders towards requirements elicitation over the whole period of requirements elicitation.*

4.1 Introduction

Successfully developing and evolving software systems requires involving the stakeholders in requirements elicitation. In the past, the number of stakeholders of a system was typically rather small. Most of them were directly accessible as members of the client's or the supplier's organizations. With the recent pervasiveness of systems and applications, the number of stakeholders of a system has drastically increased. For many systems, more or less everyone is a potential stakeholder [PB13]. Moreover, stakeholders, in particular end-users, of novel software products are often outside organizational reach, i.e., they cannot be identified among the members of the involved organizations. Typical examples include stakeholders of software systems for the sharing economy, the quantified self, and mobile applications. Established elicitation methods are not sufficient to elicit requirements from these stakeholders. In particular, they rarely scale (e.g., interviews, workshops) or hinder successful communication (e.g., polls, online questionnaires) [DP15].

Lately, RE researchers have addressed these challenges with online elicitation platforms, e.g., wikis [YWK+08] and social media platforms, e.g., Liquid RE [JM15] or REfine [SDB+15]. However, while these platforms enable the collaborative involvement of large numbers of stakeholders, this is not sufficient to motivate the stakeholders to use these platforms actively and contribute to requirements elicitation.

In particular, in order to receive substantial contributions from stakeholders outside organizational reach, an explicit motivation concept is required. In our work, we are developing such a concept based on gamification.

Gamification, the use of game (design) elements in non-game contexts [DDKN11], has successfully been applied in different domains to motivate users towards desired activities, e.g. [Sta]. Recently, first approaches of applying gamification to motivate stakeholders *within* organizational reach towards contributing to requirements elicitation, e.g., [SDB+15], [FDR+12], [LDLB16] indicate that RE can benefit from gamification.

However, research in this field is in its infancy. This may severely challenge the success of software systems: when failing to engage the consumers, technological trends might be overseen, valuable knowledge missed and end-users, customers, and clients lost [MP11]. We argue that, in particular, more research is needed on how to motivate stakeholders *outside* organizational reach towards requirements elicitation.

In the scope of our research project Garuso (**G**ame-b**a**sed **R**eq**u**irement**s** Elicitati**o**n) [Hubc], we address this gap with a motivation concept that follows the theories of experiential learning and need satisfaction and is tailored to a social media platform that combines a forum for contributing, discussing and rating needs with gamification.

In this paper, we describe the three dimensions of this concept and show how it is applied. Our work contributes to the emerging research field of involving globally dispersed groups of stakeholders in requirements elicitation.

4.2 Related Work and Background

In this section, we introduce gamification and the motivation theories relevant to our work. The context of our work is illustrated in Fig. 4.1.

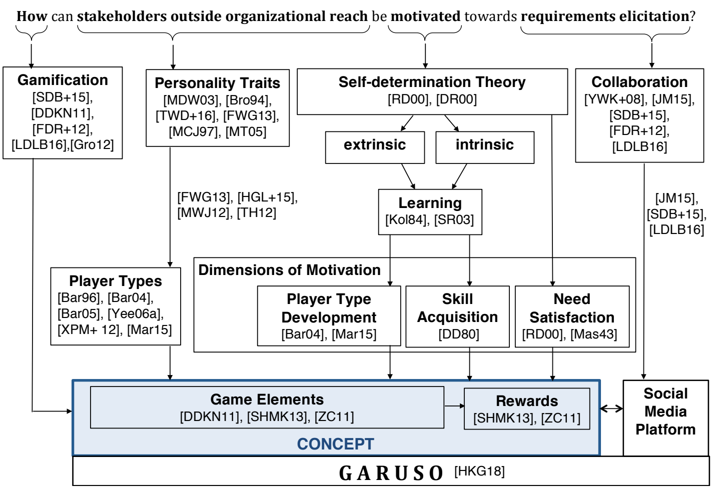


Figure 4.1: Context of our Work with Relevant References.

4.2.1 Gamification Primer Through the Lens of RE

The goal of applying gamification is to motivate users with game elements towards a desired activity, i.e., increasing the quality or the quantity of a product [Gro12]. Table 4.1 gives an overview of common and popular game elements and the rewards they represent. In software development, one of the biggest success stories of gamification is Stack Overflow [Sta], an online platform that motivates users with levels and badges towards global, collaborative issue management. When writing this paper, Stack Overflow had over 6.5 million users.

Table 4.1: Popular game elements used in gamification (based on [DDKN11, SHMK13, ZC11])

Game Element	Description
Points	They show user performance and are the most basic game element. Usually, they are earned in categories for actions taken and are used as a virtual currency, for direct feedback, to address the desire to collect, and as metric for other rewards.
Badges	They represent success and status. Thereby, they address different motivation mechanisms, e.g., the desire to collect, to achieve a goal (of earning a badge), and to get status (by having earned a badge).
Leaderboards	They represent success and status. Basically, they are a dynamic ranked list of users that shows the users' performance in a specific context.
Levels, Progress Bars	They represent status and access. Both show the progression towards a goal, but levels are also often used to give access to a distinct group of people or features.
Challenges, Quests, Missions	They represent success and trigger the urge of goal achievement by transparently showing the success of actions, e.g., earning a particular badge for gathering a specific number of points.
Limited Resources	They represent pressure by making the activities dependent on the availability of resources such as life points or time.

RE researchers have developed first game-based tools and platforms for elicitating requirements. To improve participation in RE, iThink [FDR+12], a Web-based elicitation tool, combines gamification with parallel thinking [DB89]. To involve crowds of stakeholders in the context of software product organization, REfine [SDB+15], an interactive online platform for requirements elicitation and refinement, combines gamification with crowdsourcing [DSB+17]. For both approaches, the qualitative and quantitative evaluation of their case study results indicate that the stakeholders' contributions to requirements elicitation can be motivated with gamification. Further, results of a recent laboratory experiment with a game-based platform showed that applying gamification in the context of scenario-based RE leads to requirements of higher quality and more creativity [LDLB16]. However, all approaches involved stakeholders *within* organizational reach (iThink: a class of graduate students; REfine: developers, clients, and users; experiment: employees) and did not consider the evolution of the stakeholders' experience and motivation during the elicitation process.

4.2.2 A Nutshell of Motivation within Gamification

Being motivated means *"[..] to be moved to do something"* [RD00] (p.54). People who are motivated in an activity are more engaged in this activity. Whether and how motivation can be enhanced has therefore raised major interest.

Over the last decades research in psychology have uncovered a whole spectrum of human motivation [RRR15], e.g. [Mas43], [Ski53], [DR00].

Gamification mainly refers to Self-determination Theory (SDT), e.g., [DR00], which conceptualizes motivation with respect to its driving force as extrinsic or intrinsic. People are extrinsically motivated if they are driven by an *output which is separable from the activity itself*, i.e., any kind of reward (or punishment). On the other hand, people are intrinsically motivated if they engage in an activity due to an *inherent satisfaction* of doing so. Further, SDT considers motivation within a continuum of fluctuating intensity between the two extremes of no motivation (amotivation) and inherent motivation (intrinsic motivation), and four stages of extrinsic motivation between these extremes [RD00].

With respect to extrinsic motivation, a theory of motivating activities with rewards goes back to Skinner's behaviorist theory [Ski53]. According to this theory, human behavior is conditioned and motivated with different reinforcements, i.e., rewards and punishments.

With regard to the intensity of motivation, the theory of Maslow's Hierarchy of Needs [Mas43] for example suggests that how much someone is motivated in something is influenced by how well human needs are satisfied. SDT considers three human needs as basic: *autonomy*, i.e., the feelings of being in charge, e.g., by having the power of free choice; *competence*, i.e., the feeling of having the ability to deal with a challenge; and *relatedness*, i.e., the feeling of being connected with others.

According to SDT, the more a person perceives these human needs as satisfied when being rewarded (extrinsic motivation) or while performing an activity (intrinsic motivation), the more the person's motivation shifts towards or increases intrinsic motivation. In contrast, the risk of eliminating this person's prior (intrinsic) motivation towards an activity increases the more this person perceives a lack of need satisfaction, e.g., when being controlled by the rewards [RD00]. This effect is known as overjustification, a theory tested by Lepper et. al. [LGN73].

4.2.3 Personality Traits

How people act is generally assumed to be influenced by their personality [MDW03]. Personality traits are "latent characteristics of persons that determine the way in which individuals respond to the social world they encounter" [Bro94] (p. 119), and their notion goes back to Aristotle [MDW03]. Compared to personality types, personality traits are less rigid. While people usually have one dominant personality trait, they incorporate other traits [TWD+16] of different intensities [FWG13]. For example, a person is creative (personality type) and has strong happiness as well as average confidence (two personality traits). Results of personality research further indicate that personality traits exist across cultures, e.g., [MCJ97] and are even universal, e.g., [MT05]. In the context of this work, we do not go into the details of the different traits or models, but focus on the overall idea of personality traits instead.

4.2.4 Player Types: A New Stakeholder Typology

Player types are not a perfect match to personality traits, but a good enough one [HGL+15]. Several study results show a relationship between personality and player types, e.g., [MWJ12], [TH12] and it is assumed that player types and personality traits are essentially the same construct within different contexts [FWG13]. One of the most popular player type models referred to in gamification [FWG13], [TWD+16], which we also use in our work, is the one by Bartle [Bar96], [Bar04], [Bar05]. He identified four main player types: Achiever, Socializer, Explorer, and Killer, while observing the behavior of players in Massively Multiplayer Online Role-Playing Games (MMORPGs). According to his observations, these player types are located within the dimensions of sociability (acting vs. interacting) and exploration (player-oriented vs. world-oriented) [Bar96], [Bar04]. *Achievers* act in the world and *Killers* on other players, while *Socializers* interact with players and *Explorers* with the world. Each of these player types has an *implicit sub-type* that takes actions automatically and without thinking and an *explicit sub-type* that takes them thoughtfully and with prior planning (cf. Fig. 4.2).

Recently, several player type models have evolved, e.g., [Yee06a], [XPM+12], [Mar15] and revealed three presumably general aspects. 1) The key domains *Achievement, Exploration, Sociability, Domination, Immersion* exist among most player type models [HT14].

2) At any point in time one player type is usually dominant but users are very likely to show tendencies of the other player types as well [HK14],[Mar15]. 3) Player types evolve along different paths as they get to know and better understand the virtual environment [Bar05] or system to which gamification is applied [Mar15].

4.2.5 Experiential Learning, Player Type Development, and Skill Acquisition

Experiential learning theory is a holistic theory that considers learning as a continuous process of human adaptation to the social and physical environment [Kol84]. In particular, it reflects the relationship between a person and the environment with the dual meaning of experience: the personal meaning as in 'experiencing joy and happiness', and the environmental meaning as in '20 years of experience in the job' (p. 35). Thereby, experiential learning happens within the two dimension of experimenting vs. observing and experiencing vs. conceptualizing [Kol84].

In the dimension of *experimenting vs. observing*, people learn while moving between acting and reflecting. Similarly, when entering a virtual environment, most players initially perform a path of behavioral learning, in which environmental stimuli cause human responses, followed by a path of cognitive learning, in which knowledge is acquired and manipulated [SR03].

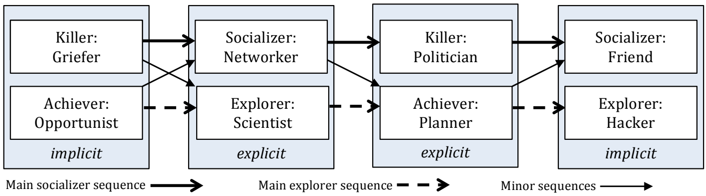


Figure 4.2: Four main player types with their implicit and explicit sub-types and three development sequences (based on: [Bar05]).

Thereby, as illustrated in Fig. 4.2 the players initially aim at understanding the basic rules and boundaries of the environment by either pushing every possible action to be better than others (*Griefer*) or by trying to advance by taking any chance (*Opportunist*). After having acquired the basic knowledge they start to cognitively process information and constantly update existing knowledge according to new situations [SR03]. Therefore, they create new actions by trial and error (*Scientist*) or by asking others (*Networker*) to achieve success in regard to the system (*Planner*) or to others (*Politician*). Finally, they have mastered all tools within the environment and understand the co-players (*Friend*) or the system (*Hacker*).

In the dimension of *experiencing vs. conceptualizing*, people learn while moving between feeling and thinking. Similarly, when acquiring skills, e.g., [DD80] people follow the desire to acquire new abilities by solving challenges. Thereby, they normally pass five stages of skill acquisition; *novice*, *advanced beginner*, *competence*, *proficiency*, and *expertise*.

4.3 Moving Towards a Motivation Concept

We developed the motivation concept in the scope of the Garuso project [Hubc]. In this section, we present our research goal, and describe the main steps of developing and applying the concept. All steps are summarized in Table 4.2.

4.3.1 Goal and Research Question

Our goal within the Garuso research project is to investigate stakeholder engagement in RE. One of the research questions addressing this goal is: *How can stakeholders outside organizational reach be motivated towards requirements elicitation?*. The concept presented in this paper contributes to answering this research question.

Table 4.2: Main Development Steps of Creating and Applying the Concept

Step	Step Description	Status
1	Interdisciplinary Literature Review	Done
2	Defining the System Boundaries	Done
3	Evaluating Methods of Stakeholder Attraction	Done
4	Conducting an Experiment	Done
5	Conceptualizing Findings	Done
6	Finalizing the Implementation	In progress
7	Running and Monitoring the Implementation	Planned
8	Evaluating the Results	Planned

4.3.2 Steps of Concept Creation and Application

In the following, we describe the development of the concept (steps one to five), and its application (steps six to eight).

1) Interdisciplinary Literature Review. The concept is based upon our previous research on gamification for collaborative platforms [HH15] and strengthened with findings presented in the related work and background section of this paper.

2) Defining the System Boundaries. We defined the system boundaries based on the following three assumptions. First, most of the stakeholders, i.e., mostly end-users of the system of interest, are outside organizational reach. Second, the platform used by the stakeholders to contribute to the elicitation of requirements of a software system is a social media platform that enables its users to collaboratively post, comment, and rate needs. Third, the stakeholders are non-experts with respect to the domain of application, i.e., the elicitation platform and the community interacting on the platform.

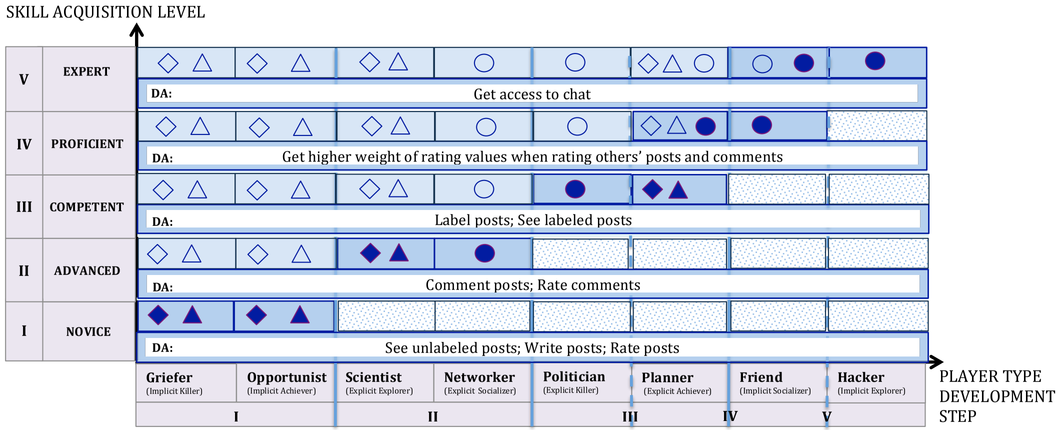
3) Evaluating Methods of Stakeholder Attraction One important question regarding the concept is how to attract the stakeholders. In the context of crowdsourcing, 'workers' are often 'hired' over paid platforms. A critical aspect of this practice is that particularly monetary rewards bear a high risk of undermining intrinsic motivation [RD00]. Another approach avoiding this risk is the use of online advertisements, e.g., Google AdWords [IG14].

We went one step further and additionally distributed picture-based advertisements (ads) that target player types [Huba] over social media. In total, we attracted almost 600 stakeholders outside organizational reach, worldwide. Further, based on previous research on stakeholder identification, e.g., [LF12] we will consider the technique of snowballing [Goo61] on the implemented Garuso platform, i.e., already identified stakeholders can recommend other (potential) stakeholders over the platform.

4) Conducting an Experiment We investigated the algorithms controlling single game elements in a field experiment with an implemented prototype of the Garuso platform[1].

5) to 8) - Conceptualizing to Evaluating. Based on the previous steps, we conceptualized our findings as presented in this paper (step 5). Currently, we finalize the Garuso platform based on this concept (step 6). Next, we will test the Garuso platform within a case study with stakeholders outside organizational reach. Thereby, we will monitor their interactions (step 7), and evaluate the results (step 8).

[1] M. Z. Huber Kolpondinos, M. Glinz, Behind Points and Levels – The Influence of Gamification Algorithms on Requirements Prioritization (submitted for publication)



The third Dimension of need satisfaction is represented by three symbols: ◆ for Autonomy, ▲ for Competence, ● for Relatedness

The symbols mark the existence of rewards that satisfy the need represented by the symbol. Filled symbols indicate newly introduced rewards, outlined ones indicate inherited rewards.

Figure 4.3: Concept to motivate stakeholders outside organizational reach towards contributing to requirements elicitation by taking actions on a social media platform. The (potential) rewards are indicated by need satisfaction symbols and access to domain activities (DAs).

4.4 Concept-based Motivation of Stakeholders

In this section, we describe the concept we developed and support the description with Fig. 4.3.

The concept follows the theory of experiential learning to consider that these stakeholders experience the elicitation process over time and thereby 1) learn with respect to the domain of application and 2) develop in terms of how they feel motivated. Along this experience, it introduces (potential) rewards and tailors them with respect to the theory of need satisfaction. It is designed to be applied on social media platforms.

4.4.1 Three Dimensions of Motivation

To consider learning and change of motivation, we follow the theory of experiential learning by applying skill acquisition levels in the dimension of experiencing vs. conceptualizing (y-axis in Fig. 4.3) and player type development steps in the dimension of experimenting vs. observing (x-axis in Fig. 4.3). During the elicitation process, the stakeholders, i.e., users of the platform, move along both dimensions. However, with respect to the context of requirements elicitation, we consider transitions between the levels of skill acquisition to influence the transitions between the steps of player type development.

In other words, while the users become more experienced during the elicitation process, they learn with respect to the domain, i.e., move one level up, which affects how they feel motivated, i.e., they move one step to the right. Every *level N/step N* intersections represents one stage in which the users are motivated with (potential) rewards that consider these dimensions. To intensify the motivational effect of the rewards on the users, they are further tailored to basic human needs. Considering that some users might change their dominant player type slower compared to increasing their skills, the rewards are inherited from one level to the next levels.

The Dimension of Skill Acquisition. For every skill level we introduce (potential) rewards and inherit them for levels above level one, thereby, access to domain activities (DAs) is considered as a reward. Following the theory of skill acquisition, a domain is only understood by people when they have reached the third level (competent) [Dre04]. Therefore, we enable the basic DAs such as posting, commenting, rating, and labeling needs, e.g., categorizing them in functional or non-functional, in the first three levels. The rules that define when users move from one level to the next are created by the requirements engineer.

The Dimension of Player Type Development. We consider the potentially high heterogeneity of stakeholders outside organizational reach by applying the two main, i.e., most common, player type development sequences (cf. Fig. 4.2). Users who follow the *main explorer sequence* proceed from Opportunist over Scientist and Planner to Hacker. The ones following the *main socializer sequence* develop from Griefer over Networker and Politician to

Friend. To address both sequences in the concept, we combined for every sequence position the two corresponding player types to one step. For example, step II contains the Scientist (position two in the main explorer sequence) and the Networker (position two in the main socializer sequence). Originally, the sequences have four player types.

With respect to the dependency to the dimension of skill acquisition (which has five levels), we created step IV by extending the phases of the Planner and the Friend types. Our rationale for this decision was that a) all basic DAs are enabled in the previous levels, and b) these player types fit very well to the skill level of proficiency.

The Dimension of Need Satisfaction. Based on the hierarchical structure [Mas43] and the relevance [RD00] of human needs, and with respect to the context of experiential learning we explicitly address autonomy and competence up to level three, and focus on relatedness on higher stages. To preserve the readability of Fig. 4.3, we represent the dimension of need satisfaction with symbols (diamond for autonomy, triangle for competence, circle for relatedness).

The Rewards. We introduced two different kinds of rewards in the concept: rewards that depend on game elements, e.g., status, access, and power [ZC11], and rewards that depend on the domain activities.

Symbols indicate the existence of (potential) rewards that are mostly based on game elements, with respect to the three dimensions.

For example, the circles in stage five (*level V / step V*) indicates rewards, which meet the criteria of skill acquisition level *Expert* and target the motivational triggers of the player types *Friend* and *Hacker*, while addressing the human need of *Relatedness*. Filled symbols indicate newly introduced (potential) rewards, while outlined symbols indicate reward possibilities that are inherited from previous levels.

Rewards that depend on DAs consider level-based access to activities that can be taken on the platform. For every level the activities are enabled for all player types, e.g., label posts on level III for player type steps one to five.

4.5 Example of Application

In this section, we present an example of how to design the rewards based on the concept. The example is supported by Fig. 4.3 and the concrete rewards used in the example are summarized in Table 4.3.

4.5.1 Rewards on Different Stages of Stakeholder Development

For every stage, we first give an overview of the users' state of experience and goals, a general description of the reward criteria, and a concrete example. Due to space constraints we focus on rewards that are based on game elements.

Level I / Step I. Stakeholders access the platform for the first time. With their actions, they pursue the goal to explore the boundaries and basic rules of the domain while seeking to fulfill the need of autonomy and competence. *Reward Criteria:* On this stage the rewards are diverse, and address exclusiveness (Griefer). Further, they can be earned in different ways and to different times (Opportunist). *Example*: the diversity of rewards can be addressed by introducing one point category per DA. Further, exclusiveness, e.g., having received the most votes for a post, can be rewarded with a badge. The variety to achieve a reward can be addressed by granting access to a number of basic challenges, i.e., challenges that depend on the numbers of points per point categories. The urge for becoming better over time can be addressed by announcing the possibility to earn corresponding badges in the future, i.e., the next stage.

Level II / Step II. In this stage stakeholders are considered to be familiar with the basic aspects of the domain. With their actions they pursue the goal to cognitively process information and constantly update existing knowledge according to new situations while striving for fulfilling the needs of autonomy, competence, and relatedness. *Reward Criteria:* The rewards on this stage encourage exploring the domain with respect to the system (Scientist) and to the community (Networker). *Example*: getting more familiar with the system can be addressed with access to a number of advanced challenges and further be supported by announcing the possibility to earn corresponding badges in the next stage. Further, social influence can be increased by revealing the number of ratings for all posted needs.

Table 4.3: Example Rewards with Respect to the Motivation Concept

Stage	Player Type	Human Need	Example Reward
Step V Level V	Hacker	R	Get access to the expert circle
	Friend	R	Get the right to endorse others
Step IV Level IV	Friend	R	Get information about the authors' names for all posts
	Planner	R	Earn an award for having reached this level
Step III Level III	Planner	C	Earn a holistic badge
		A	Receive information about the distance to the next stage
	Politician	R	Get access to leaderboards
Step II Level II	Networker	R	Get information about ratings
	Scientist	C	Get information about future badges
		A	Get access to advanced challenges
Step I Level I	Opportunist	C	Receive information about future badges
		A	Get access to basic challenges
	Griefer	C	Earn a badge for being exclusive
		A	Earning points per activity

Human Needs: Autonomy (A); Competence (C); Relatedness (R)

Level III / Step III. Now, the stakeholders are more experienced. With their actions they focus on the goal to achieve success with respect to relatedness, competences, and autonomy. *Reward Criteria:* On this stage the rewards focus on power with respect to the urge to get more influence on others (Politician) and to beating the system (Planners). *Example*: the influence on others can be addressed by granting access to leaderboards. Further, the urge to beat the system can be considered by revealing the number of points that are needed to reach the next stage, and by introducing a holistic badge, i.e., one that can only be earned with respect to all DAs.

Level IV / Step IV. On this stage, the stakeholders know the relevant features of the domain. With their actions they focus on the goal to increase their influence on the system and their understanding of the community with respect to autonomy and relatedness. *Reward Criteria:* These rewards consider mastery over the system (Planner) and increased influence on the community (Friend). *Example*: mastery can be addressed with an award for reaching this stage and the influence in the community can be increased by revealing the authors' names for all posted needs.

Level V / Step V. Here, stakeholders have become experts with respect to the domain. Their actions follow the goal to get status in the community with respect to relatedness. *Reward Criteria:* Rewards in this stage focus on getting more influence in the community (Friend) and being honored (Hacker) by the system. *Example*: the right to endorse others and access to the circle of expert users can be granted.

4.6 Discussion

The concept presented in this paper contributes to answering the research question: *How can stakeholder outside organizational reach be motivated towards requirements elicitation?* Our concept addresses the challenge of not knowing these stakeholders, characterizes them with player types and keeps them motivated over time with rewards that are designed with respect to skill acquisition, player type development, and need satisfaction. The concept itself neither defines a number of rewards nor concrete rewards. Instead, it gives guidance of how to design rewards at a specific stage during the elicitation process.

We create an example that suggests fourteen rewards. Eight of them refer to the human needs of autonomy and competence, and six to relatedness. With respect to the focus on collaboration, this choice seams reasonable. However, other outcomes are possible for different purposes.

4.7 Threats to Validity

We are aware that this research is prone to threats to validity. In this section, we discuss the three threats that we consider most important. First, limiting the DAs for domain experts on lower levels could negatively affect the identification of relevant requirements. To better integrate experts, we suggest to complete our approach with traditional elicitation techniques, and to apply a questionnaire to place users in different levels when accessing the platform for the first time. Second, large numbers of posts could challenge their prioritization. We suggest to address this threat with collaborative filtering, e.g., [LF12] and user feedback analysis, e.g., [GAB15]. On the other hand, a small number of initially identified stakeholders might demotivate early users due to a limited number of interactions. We suggest starting with a known number of stakeholders (within organizational reach), e.g., developers and clients, who can identify other stakeholders by applying snowballing.

To make the process of stakeholder identification independent of these key stakeholders, we further propose to attract others with distributed ads that specifically address different player types. Moreover, we suggest that the rules per level depend on relative criteria, e.g., the number of active users, or posts. Third, gamification only works if people already have some inherent motivation in the product or service on which gamification is applied [Det12]. As being a stakeholder implies having some interest in the software system under consideration [GW07], we do not consider the lack of intrinsic motivation as a threat.

4.8 Conclusion and Future Work

We presented a concept to motivate stakeholders outside organizational reach towards contributing to requirements elicitation by taking actions on a social media platform. The concept addresses the challenge of not knowing these stakeholders and considers that their experience and motivational factors change during the elicitation process. The presented research is preliminary and mostly theoretical. Nevertheless, we believe it will substantially contribute to the body of knowledge on motivating stakeholders outside organizational reach in RE due to its multidisciplinary foundation. However, more work is needed and we encourage other researchers to test and evolve the concept. In our future work, we will implement and evaluate it in a field case study.

Chapter 5

Behind Points and Levels

Original publication:
Behind Points and Levels – The Influence of Gamification Algorithms on Requirements Prioritization
M.Z. Huber Kolpondinos and M. Glinz
25th IEEE International Requirements Engineering Conference

Abstract

Prioritizing requirements is a crucial ingredient of successful Requirements Engineering (RE). The popular prioritization techniques assume that stakeholders are known and can be mandated to contribute to the prioritization process. This prerequisite no longer holds for many of today's systems where significant stakeholders (end-users, in particular) are outside organizational reach: they are neither known nor can they be identified among the members *of the involved organizations. Classic techniques for involving these stakeholders such as polls or questionnaires are neither interactive nor collaborative, which is detrimental for prioritization. Social media enable collaborative prioritization, but fall short in motivating stakeholders outside organizational reach to participate voluntarily. In this light, we are developing the* Garuso *platform, which combines social media with gamification for motivating stakeholders. While first approaches to employing gamification in RE are promising, research is still in its infancy. Especially, little is known about the influence of the gamification algorithms controlling single game elements on the stakeholders' activities. In this paper we report on a field experiment in which we investigated this influence with Garuso. We found statistically significant differences between different algorithms controlling single game elements on the contributions of stakeholders to the prioritization of requirements.*

5.1 Introduction

Successful development and deployment of a software system crucially depends on knowing the priority of the elicited requirements [ASIM14]. Involving the stakeholders [GW07] of the system in the prioritizing process, in particular the end-users, increases the success of the software system [MP11]. As stakeholders typically do not have the same needs, they should be able to contribute collaboratively to the prioritization process [YWK$^+$08, KSK14].

In requirements engineering (RE) research and practice, a wealth of prioritization techniques [ASIM14] have been developed and applied. The most popular and successful ones, such as ranking or grouping assume that the stakeholders are known and available. Hence, with the transition from dedicated software systems used by trained users to today's world of ubiquitous apps and globally offered services, the established prioritization techniques are seriously challenged. Significant stakeholders of these systems, in particular, end-users, are typically not known and also outside organizational reach, i.e., they cannot be identified among the members of the involved organizations. If these stakeholders are ignored, valuable knowledge may be missed [MP11]. Online polls and questionnaires are established technical means for involving such stakeholders. As neither of them is collaborative, they are not well suited for requirements prioritization. More recently, social media have been proposed for performing collaborative RE tasks such as requirements prioritization [LDHH09, JM15].

However, social media approaches do not addresses the motivation problem: stakeholders outside organizational reach need to be motivated to contribute voluntarily, as they cannot be mandated to contribute.

Here, gamification, the use of game elements in non-game contexts, can provide a solution. First approaches applying gamification in RE are promising, e.g., [FDR+12, SDB+15]. However, this research is still in its infancy: little is known about the influence of single game elements and the algorithms controlling them on the stakeholders' RE activities, and nothing with respect to stakeholders outside organizational reach. This may lead to mistakes when applying gamification, which bears the risk of damaging the stakeholders' inherent motivation [KTCK12].

In this context, we are developing the Garuso (**G**ame-b**a**sed **R**eq**u**irement**s** Elicitati**o**n) platform, which combines a forum for contributing, discussing and rating needs with game-based techniques for motivating potential stakeholders to contribute to these RE activities.

In this paper, we report on the results of a field experiment in which we investigated the influence of the algorithms that control the popular game elements *points* and *levels* on the contributions of stakeholders outside organizational reach to the prioritization of requirements. The experiment was conducted on the Garuso platform. We found that using different algorithms indeed has a statistically significant influence on the contributions of stakeholders to prioritization.

The remainder of this paper is structured as follows. We provide background information and related work in Sect. II. In Sect. III, we give an overview of Garuso. Then we describe the experiment in Sect. IV. The results are presented and discussed in Sect. V-VIII. Sect. IX concludes the paper.

5.2 Background and Related Work

This section provides background information and related work on prioritization and gamification in RE. Further, we motivate the need for studying the gamification algorithms.

5.2.1 Requirements Prioritization

Prioritizing requirements means to determine their relative necessity [ASIM14] with respect to business goals, available resources, and existing constraints [Wie99]. It is an iterative process that can be performed during the entire lifecycle of a software system [BA05]. The prioritization techniques used by requirements engineers and practitioners are well established and manifold [MG12], [ASIM14]. For example, requirements can be ranked by multiple criteria, e.g., Cost-Value Ranking [KR97], or in relation to other requirements, e.g., Pairwise Comparison [Kar96]. For achieving scalability, these techniques can be supported with data mining and machine learning techniques [MG12].

Recent approaches in requirements prioritization increasingly focus on social interactions that collaboratively involve all stakeholders [TCBB09]. For example, WikiWinWin [YWK^{+}08] enables quick collaboration on the Web. Stakeholders can brainstorm new needs collaboratively and rate each others' contributions with respect to different predefined criteria, e.g., business importance or ease of realization. Online platforms typically enable the stakeholders to prioritize contributed needs in a more sophisticated way. For example, the approach by Lohmann et al. [LDHH09] enables stakeholders to rate shared needs on a scale and also to vote for or against them. Similarly, the collaborative RE framework by Konaté et al. [KSK14] uses two consecutive prioritization steps: (1) voting for or against needs based on a personal perception of importance; (2) selecting key needs among those that received the most votes. Most recently, Liquid RE [JM15] suggests to grant the stakeholders the right to delegate their vote to other stakeholders.

However, motivating stakeholders, particularly those outside organizational reach, towards voluntarily contributing to requirements prioritization is still an open issue. Here, gamification offers an interesting chance.

5.2.2 Gamification in Requirements Engineering

Gamification is the use of game elements in a non-game context [DDKN11]. It harnesses the motivational power of games and applies it to real-world problems [LH11]. A crucial prerequisite for the success of gamification is that people already have an inherent motivation towards the product or service to which gamification is applied [Det12]. Stakeholders have by definition an interest in the software system under consideration [GW07] and therefore meet this prerequisite.

The involvement of end-users in RE activities has been identified as a key challenge for the success of a software system [KKLK05]. Recently, requirements engineers have started to address this challenge with gamification. First approaches that apply gamification in the context of requirements elicitation and prioritization show encouraging results with respect to the engagement of stakeholders *within* organizational reach. For example, two case studies involving the web-based gamification environment iThink [FDR+12] yielded highly satisfying results with regard to the number and quality of the generated requirements. Similarly, results of a more recent case study involving the online platform REfine [SDB+15] show a positive influence of gamification on collaborative RE activities such as suggesting, branching, and prioritizing needs and comments.

Most recently, in the context of scenario-based RE, the results of a controlled laboratory experiment showed that the participants who were motivated with game elements on a digital platform produced user stories that led to requirements of higher quality and creativity than those produced without gamification [LDLB16]. However, to the best of our knowledge, no studies on the involvement of stakeholders *outside* organizational have been published so far.

5.2.3 The Need for Investigating Single Game Elements

To be motivated is a delicate state on a scale between no motivation (amotivation) and absolute motivation (inherent motivation) [RD00]. Badly designed motivation strategies can push inherently motivated people towards the state of amotivation, e.g., by overjustification [LGN73]. Examples of badly designed gamification include designs that control the users too much, i.e., give them no autonomy on their activities, or provide rewards that are meaningless for them. In particular, the random application of game elements has been criticized for achieving results below expectations and for dulling the users [KTCK12].

In software engineering (SE), the lack of a systematic methodology on how to apply gamification to increase user engagement has been identified as a research gap and threat [PGBP15]. Also, the small number of studies researching the effects of single game elements (compared to the number of studies on general effects of gamification, i.e., regarding all applied game elements together as one black box) has been criticized [DT13].

In RE, the need to investigate the effects of gamification on stakeholder engagement more thoroughly also has been recognized. For example, the creators of the iThink approach [FDR+12] (see above) identified the lack of an experiment as a limitation of their work [RFPdS14]. Further, researchers who investigated general effects of gamification have emphasized the need for testing game elements in isolation [LDLB16].

5.3 Garuso

The experiment we report on in this paper was conducted on the Garuso platform that we are developing at the University of Zurich. To understand the context of the experiment, we briefly describe the architecture of the Garuso platform (Fig. 5.1), its user interface (Fig. 5.2), and the rating scheme used for prioritization (Fig. 5.3).

Garuso (**G**ame-b**a**sed **R**eq**u**irement**s** Elicitati**o**n) is a research project that investigates stakeholder engagement with respect to the collaborative elicitation and prioritization of requirements. The conceptual basis of Garuso is a three-dimensional motivation concept [HKG17b] that we created based on theories of experiential learning and motivational psychology.

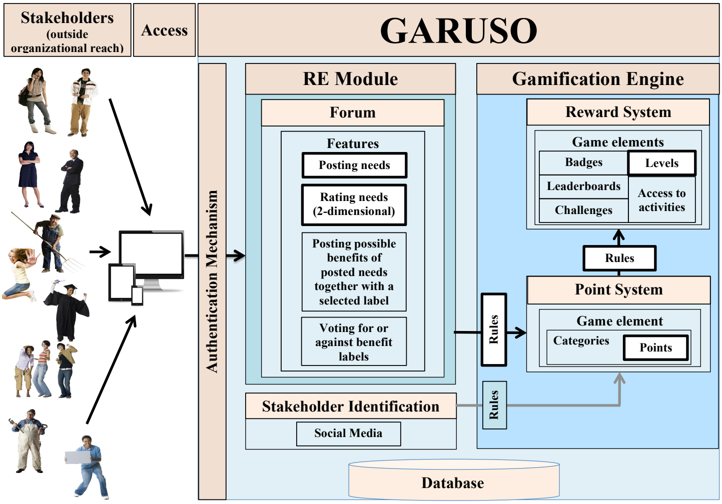


Figure 5.1: The architecture of the Garuso platform. The features in bold frames indicate the activities and game elements that were enabled in the experiment.

5.3.1 The RE Module

The *RE module* addresses asynchronous communication and creative contributions. It offers four RE related features that facilitate the collaborative elicitation and prioritization of requirements with respect to the software system of interest: on the Garuso platform, stakeholders can (1) post their needs with text and/or images, (2) rate each others' needs, (3) post and label benefits for all the posted needs, and (4) vote for or against the labels of these benefits. For the experiment, we limited the available features to (1) and (2).

5.3.2 The Gamification Engine

The *gamification engine* offers means to motivate stakeholders towards using the features offered by the *RE module*. It includes a point system, a reward system, and rules.

Points and Rewards. The *point system* uses the game element *point* and defines different point categories. It is directly affected by the activities performed by the platform users. The *reward system* uses the game elements *badges*, *leaderboards*, *challenges*, *levels*, and *access* to reward the users.

It is built on top of the point system and directly affected by a user's earned number of points per category. For the experiment, we limited the game elements to points and levels.

The Rules. The *rules* govern the game elements in the point system and the reward system. They define how many points of which categories users *earn* for their activities on the platform, and how many points of which categories they *need* for each reward. The rules are implemented with *algorithms*.

Stakeholder Identification. The *stakeholder identification* module enables stakeholders to invite other potential stakeholders over different social media channels to participate. This approach is known as snowballing [Sco12] and was previously applied in RE for stakeholder identification [LQF10b]. To ensure equal basic knowledge of the participants, we did not enable stakeholder identification for the experiment.

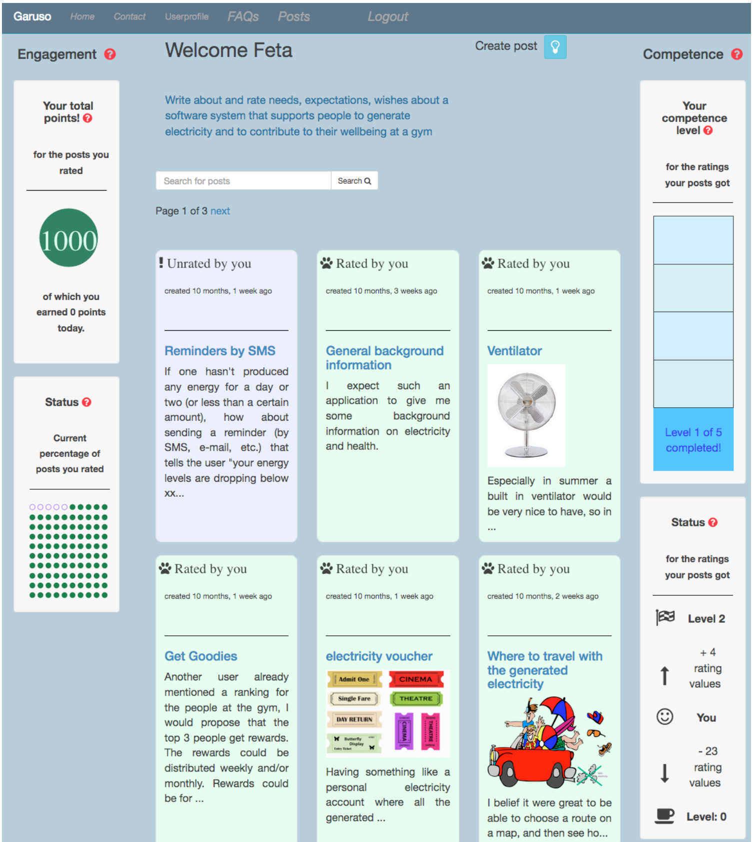


Figure 5.2: The UI of the Garuso platform. Left sidebar: point overview; center: posts, search field, button to create a post; right sidebar: level overview.

5.3.3 The Garuso User Interface

Fig. 5.2 shows a screenshot of the user interface (UI) main page for user *Feta*, one of our experiment participants. The left sidebar shows the user engagement: earned points are displayed in the upper part and the percentage of rated posts in the lower part. *Feta* has currently earned 1000 points and rated 95 percent of all posts. The center part shows a welcome message, a button for creating posts, and a search field, followed by all posts of Feta's group in pages of nine posts each. To balance their visibility, the posts are randomly ordered over time. Further, the pages can be switched manually.

Posts that the user has not yet rated are displayed in rose, while the rated ones are displayed in green. The user's own posts (which she or he cannot rate) are colored in blue. In Fig. 5.2, *Feta* has rated five posts and one post left to rate. The right sidebar shows the user competence. The user's current level is displayed graphically in the upper part and her or his status in the lower part. User *Feta* is currently on level one, needs four more rating values for achieving level two, and may lose 23 rating values until falling back to level zero.

5.3.4 Rating Scheme and Rating Values

The rating of posts is facilitated with a two-dimensional rating scheme (Fig. 5.3). The rating scheme is available in the detailed view of a post, which opens when clicking on a post on the UI main page. It offers ten rating options that each are represented by a button. Nine options are grouped in a matrix where the x-axis denotes the popularity and the y-axis the relevance of the post as perceived by the user. For example, the top right button indicates that the post is liked and relevant to the software system of interest. The tenth option allows users to express that they do not want to rate a post.

Users can change their ratings at any time. With this feature, we take the natural flow of interaction into account, which can also be observed in group elicitation methods [NE00] with physically present participants.

The rating values depend on the selection in the rating scheme. Both dimensions of the matrix in that scheme have a value range of [-1,1].

Figure 5.3: The rating scheme with nine buttons to rate the relevance and the popularity of a post and one button to confirm not wanting to rate the post.

We take the sum of both dimensions, yielding a range of [-2,2] for the rating value. For example, the rating *irrelevant&dislike* yields a rating value of minus two, *relevant&like* yields two, *relevant&neutral* yields one, and a *neutral&neutral* rating yields zero. *No rating* also yields a value of zero.

5.4 The Experiment

We ran a field experiment on the Garuso platform to study the influence of the algorithms controlling the individual game elements of the *Gamification Engine* on collaborative requirements prioritization, which ist a typical RE activity performed on the platform. As game elements, we chose *points* and *levels* which belong to the most popular elements in gamification [DDKN11], [SHMK13] and have a high probability of also being known to people outside of a game context. The platform features required for prioritization are *post* and *rate*. With respect to the nature of an experiment, in particular for isolating the dependent variables, we disabled all other features of the platform.

The software system for which the participants posted and rated needs on the Garuso platform, is part of a smart living project [Emp] in which the energy produced by people when working out in a gym is used to generate electricity. The purpose of the software system is to motivate people towards using such enhanced workout equipment. We call it the *Smart Workout Motivation System* or *SmaWoMo* for short in the remainder of this paper.

Twenty people participated in the experiment that we ran over a period of twelve days from July to August 2016.

5.4.1 Goal, Research Questions and Hypotheses

We followed the Goal-Question-Metric (GQM) approach [Bas93] to define our goal and refine it into research questions and hypotheses as presented in the following. The metrics we used are explained in sub-section 5.4.4.

Our goal is to ***investigate*** *the effects that algorithms controlling game elements have on RE activities undertaken by users of the Garuso platform* ***for the purpose*** *of collaborative requirements prioritization* ***with respect to*** *user engagement and user acceptance* ***from the point of view*** *of stakeholders outside organizational reach* ***in the context of*** *a field experiment.*

We address this goal with the following two research questions and the corresponding hypotheses.
RQ1: What is the influence of algorithms calculating the number of points stakeholders get for rating needs posted by others on the engagement of these stakeholders?

H_0-1: Algorithms calculating the points stakeholders get for rating others' posted needs have no influence on the engagement of these stakeholders.

RQ2: How do algorithms mapping the values of the ratings the stakeholders received for their posted needs to levels influence the average stakeholder acceptance of posted needs?

H_0-2: Algorithms mapping the sum of received rating values of posted needs to levels have no influence on the average stakeholder acceptance of posted needs.

5.4.2 Experiment Design

To test our hypotheses, the first author of this paper conducted a field experiment with a between subject design [CGK12]. Therefore, the participants were randomly assigned to the treatment group (TG) or control group (CG). The two groups used different instances of the Garuso platform, i.e., they did not interact with each other in any conceivable way, and we did not tell them about the existence of two groups. Further, all contributions were anonymous, e.g., the author and rating values of others' posts were not disclosed. Initially, we seeded three equal posts in both groups and repeated this step three times during the experiment to ensure the participants had enough posts to rate.

To properly define the variables and metrics we first discussed the experiment design within a group of senior researchers in the fields of RE, HCI, and Psychology, and implemented the algorithms and layout of the Garuso platform based on these results. Second, we informally tested the usability of the Garuso platform by involving these senior researchers.

To strengthen the conclusion that can be drawn from the experiment, we split the field experiment for each of the groups in two sub-experiments. The *point sub-experiment* considered the direct aspect of rating, i.e., the number of points a participant earns when rating a post for the first time. The *level sub-experiment* considered the indirect aspect of rating, i.e., the value the author of the post earns based on the rating choice made by the participant who rates the post.

5.4.3 The Participants

We recruited the participants from a group of 120 people who had participated in a previous online survey [Hubb] about the Smart Workout Motivation (SmaWoMo) system and had indicated their interest in a follow-up activity. We sent an e-mail message to these people, informing them that they could further express and discuss their needs about the SmaWoMo system on the Garuso platform during a period of twelve days. The message included a link to the registration page of the Garuso platform. 23 persons actually registered. However, two of them did not contribute anything and one only registered when the experiment was already over. So we had 20 people who actively participated in the experiment.

Due to the selection process, the participants can be considered to have the same basic knowledge about the SmaWoMo system. At the beginning of the experiment we only told them that their task was to discuss their needs with respect to SmaWoMo by contributing and rating posts on the Garuso platform.

Table 5.1: Overview of the participants

		CG	TG
	Number	11	9
	Completely unknown	7	4
Initial Contact Channel	Mass e-mail	8	8
	Facebook	1	1
	Intranet	2	0
Demographics	Countries[1]	3	4
	Average Age	32	31
	Gender (female/male)	6/5	4/5
Application Domain: *Performing workouts*	Never	4	0
	Not anymore	4	5
	Currently	3	4
Application Domain: *Knowledge about renewable energies*	Below average	2	3
	Average	7	4
	Above average	2	2
	Expert	0	0

[1]Participants per country: CG: CH:7, DE:3, GR:1; TG: CH:6, BG:1, IT:1, US:1
CG: Control Group, TG: Treatment Group

We did not disclose the existence of an experiment and never made any suggestions to perform certain activities.

To reflect the real world situation of an arbitrary group of stakeholders outside organizational reach, the participants were randomly assigned to the treatment group (TG) or to the control group (CG) when registering. As the two non-contributing registrants had been assigned to the TG, we eventually had nine people in the TG and eleven in the CG.

At the first login, the participants were asked to complete a short questionnaire. All of them did so. The results are summarized in Table 5.1 and explained below. As mentioned above, all participants had participated in a previous online survey. For that survey, we had sought participants over multiple channels, in particular:

(1) a mass e-mail via the distribution office of the University of Zurich, (2) a public Facebook post, and (3) the intranet of our research partner Empa. From the 20 participants in our current experiment, sixteen had been found initially over channel (1), two over channel (2) and two over channel (3). The majority of the participants were completely unknown to the authors of this paper, i.e., we did not have any known connection to them. Due to these characteristics, all participants can be considered to be stakeholders outside organizational reach.

With respect to demographics, the two groups were pretty well balanced. Concerning application domain knowledge, the groups were overall balanced, with some differences in the sub-domains: four participants in the CG have never performed workouts, while all participants in the TG have workout experience. On the other hand, the number of participants perceiving themselves as knowledgeable about renewable energies is higher in the CG than in the TG.

5.4.4 Variables and Metrics

To test our two hypotheses, we divided our experiment into two sub-experiments with an independent and a dependent variable each. The independent variables are the algorithms that control the game elements *points* and *levels*. The design of these algorithms follows the strategy of *experiencing success*, which is a common strategy for motivating players in game design [NWR16] and users in gamificiation [ZC11].

Table 5.2: Independent Variables (Algorithms) with Respect to the Two Sub-Experiments and the Two Experiment Groups

	Control group	**Treatment group**
Point Sub-Experiment	Linear function: points equal to percentage of rated posts	Binary function: 0 points for rating < 100% posts; 100 points for rating all posts
Level Sub-Experiment	Slowly increasing difficulty up to level four, decreasing difficulty for reaching level five	Rapidly increasing difficulty up to level three; decreasing difficulty above level three

We considered two aspects of this strategy: (1) the aspect of *mastering challenges*, which is related to exploring; (2) the aspect of *fast progress*, which is related to achieving [Bar05]. For both sub-experiments, the independent variables are summarized in Table 5.2 and subsequently explained together with the dependent variables.

Point Sub-Experiment. The independent variable in this sub-experiment is the algorithm that defines the number of points a participant earns for rating a post. We tested two values of this variable by using different algorithms for the TG and the CG. The TG algorithm uses a *binary function*, which addresses *mastering challenges*: per day, the number of points a participant receives is either zero as long as the participant has not rated all posts, or 100 as soon as the participant has rated all posts. The CG algorithm addresses *fast progress* with a *linear function*: per day, the number of points a participant receives is proportional to the percentage of the posts (s)he has rated. Both functions are normalized with the same maximum of points that can be earned per day. When the maximum is reached, it cannot be lost again.

The dependent variable in this sub-experiment is the *stakeholder engagement*. We argue that the number of posts a participant rates is an indicator for engagement. We measure this variable by calculating the number of all ratings as follows: (a) For visualizing participant behavior over time, we measure the average number of ratings per logged in participant for every day. (b) For hypothesis testing, we measure the total number of ratings for every participant over the full duration of the experiment.

Level Sub-Experiment. The independent variable in this sub-experiment is the algorithm that determines the competence level that a participant reaches based on the sum of all rating values that the posts of this participant have received from other participants. Again, we tested two values of this variable by using different algorithms for the TG and for the CG. Both algorithms address *mastering challenges* by initially increasing the difficulty to achieve the next level and *fast progress* by then switching to decreasing the difficulty for achieving the highest levels. The algorithms differ in the deltas required to achieve the next levels. This approach is also found in the literature, e.g., [NWR16] and in existing systems, e.g. Stack Overflow [Sta]. In the TG algorithm, we increase the delta to reach the next level up to level three (26 rating values to reach level two, 36 rating values to reach level three) and then progress with decreasing deltas (29 and 7 rating values to reach levels four and five, respectively). In the CG algorithm, levels two and three are easier to achieve than in the TG (with deltas of 10 and 24 rating values), while achieving levels four and five is more difficult (with deltas of 36 and 28 rating values).

For both groups, the calculation of the rating values is equal (cf. Sect. 5.3.4) and the deltas are normalized for the levels one and five with two points and 100 points, respectively.

The dependent variable in this sub-experiment is the *stakeholder acceptance* of posts. We argue that the higher the value of a rating given by other participants, the higher is the acceptance of the post. We measure this variable by calculating the sum of all rating values as follows: (a) For visualizing participant behavior over time, we measure the average cumulative value per post and registered participant for every day. (b) For hypothesis testing, we measure the total value for every participant over the full duration of the experiment.

5.5 Data Collection and Analysis

During the experiment we monitored all user activities on the Garuso platform and stored the data in a database for subsequent analysis [HK].

We analyzed the data in three ways: (1) we calculated the average of the metrics relevant to evaluate the dependent variables for both groups to investigate how the samples are represented (Table 5.3); (2) we plotted the values of the dependent variables in both sub-experiments over the twelve days of the experiment to see how the values changed over time (Fig. 5.4 and 5.5);

(3) for testing our hypotheses, we analyzed the values of the two dependent variables for every individual participant in the TG and in the CG (Table 5.4).

If a participant contributed continuously over the duration of the experiment, thereby producing a total of n ratings, we consider this to be a stronger engagement than that of a participant who logged in just a few times, also producing a total of n ratings. The same consideration applies for the total sum of rating values that a participant received. Thus, we normalized our data for each participant with the number of login days vs. total number of experiment days before we tested the hypotheses:

$$value_{normalized}(p_i) = value_{observed}(p_i) * \Sigma[login\ days]/[total\ days]$$

where p_i is the ith participant and $total\ days = 12$.

To determine a proper test for our hypotheses, we conducted a pre-evaluation in which we tested the data for normal distribution and equality of variances. The results are presented in the row labeled *Pre-Evaluation* of Table 5.4. Due to the small sample sizes we used the one-sample Kolmogorov-Smirnov (KS) test [MJ51]. For both sub-experiments the KS test yielded a result with $p > 0.05$, i.e., not significant. Thus, we can assume normal distribution for all our data. The Levene test that we performed next yielded $p > 0.05$. Therefore, we can assume equality of the variances. Based on these results we ran the t-test on the hypotheses for both sub-experiments. To conclude the hypothesis testing, we evaluated the magnitude of the test results by calculating the effect size (the Pearson correlation coefficient) and classifying it according to Cohen [Coh92].

5.6 Results

The results of the two sub-experiments answer our research questions and give strong evidence that the way how algorithms are (reasonably) applied within a game-based elicitation platform has an influence on the contributions of stakeholders outside organizational reach to requirements prioritization.

We first give some descriptive data for the two sub-experiments. Then we present the results of the two sub-experiments. Finally, we report on the results of a follow-up survey.

5.6.1 Overall Descriptive Data

In Table 5.3 we present the average values for login days, ratings, and posts as well as the average rating values for both the TG and the CG. These results indicate that the different gamification algorithms had an influence on the performance of the participants. While the rating values per post are similar for both groups, the number of activities per participant are higher within the TG.

Table 5.3: Average Data of the control and the treatment group

Metrics	Control Group	Treatment Group
#login days[1]	4.09	6.11
#ratings[1]	11.09	21.33
#posts[1]	1.27	2.22
Σ[rating values][2]	7.21	7.85

[1]Per participant [2]Per post

Subsequently, we present the detailed results for the two sub-experiments which confirm that the gamification algorithms indeed influence requirements prioritization.

5.6.2 Point Sub-Experiment

In the point sub-experiment we investigated the influence of gamification algorithms on the *stakeholder engagement* with respect to requirements prioritization by measuring the number of ratings that posts on the Garuso platform received. The results indicate that the way how gamification algorithms calculate the number of points earned for rating requirements has a significant influence on the number of ratings.

Observation. Figure 5.4 shows the number of ratings per day. We were interested in individualized results and therefore normalized this value for each day with the number of participants who had logged in on that day.

The graphs of the two groups have similar tendencies, but different characteristics. The values are high in the first two days, fluctuate within a range of approximately four between days four and nine, and significantly decrease afterwards. Both graphs increase three times in the second week and have their maximum peak in the second half of the experiment. The major difference appears between day three and four. Here, the sum of ratings in the TG increases while the corresponding value in the CG decreases and then remains lower than in the TG except for one day.

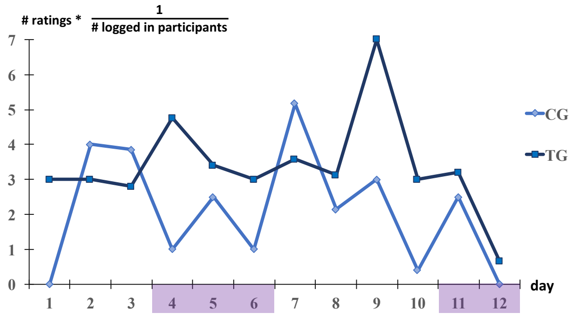


Figure 5.4: Number of ratings per logged in participant for every day. The weekends and a public holiday (day 6) are marked with grey.

Hypothesis Testing. To investigate if the differences of the observed effects between the two groups are significant, we tested the corresponding hypothesis with a t-test.

H_0-1: Algorithms calculating the points stakeholders get for rating others' posted needs have no influence on the engagement of these stakeholders.

Table 5.4 summarizes the test results. The descriptive statistics of the TG (μ=11, σ=6 with n=9) in which participants only earned the daily maximum of 100 points when rating all the posts of a day are higher compared to the ones of the CG (μ=5, σ=5.5 with n=11) in which participants earned points equal to the percentage of the posts they rated. The result of the t-test is significant at $p \leq 0.05$, so we can reject our null hypothesis. The effect size for this result is r=0.47, which represents a medium effect. This shows that the significance of our test results is meaningful.

Table 5.4: Overview of the experiment results

		Point Sub-Experiment		Level Sub-Experiment	
		Control Group	**Treatment Group**	**Control Group**	**Treatment Group**
Descriptive Statistics	μ	5.02	11	1.52	4.32
	σ	5.54	6.04	1.7	1.91
Pre-Evaluation	Normal Distribution[1]	0.139	0.2	0.2	0.2
	Variance equality[2]	0.796		0.589	
Significance Test[3]	p-Value	0.033		0.003	
	t-Value	-2.309		-3.469	
Magnitude	Effect Size[4]	0.478		0.633	

[1]Kolmogorov-Smirnov test (p-value) [2]Levene test (p-value) [3]t-test [4]Pearson (correlation coefficient r)

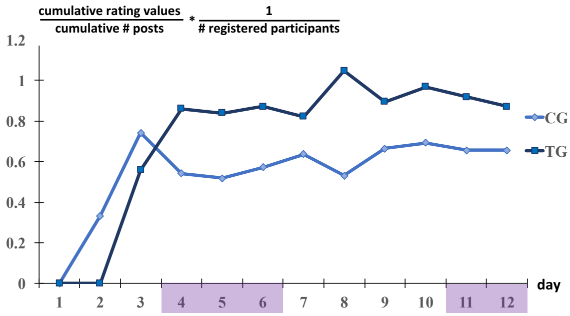


Figure 5.5: Average cumulative rating values per post and participant for every day.

5.6.3 Level Sub-Experiment

In the level sub-experiment, we studied the influence of gamification algorithms on the average *stakeholder acceptance* of posts by measuring the total rating value that the posts received on the Garuso platform.

The results indicate that the way how gamification algorithms map the values of ratings for posted needs to levels has a significant influence on the acceptance of the posted needs by the stakeholders.

Observation. Figure 5.5 shows the average cumulative rating value per number of posts and day. We were interested in the cumulative results over a period of time and therefore normalized this value for each day with the number of participants who had registered up to that day.

Again, the two graphs have similar tendencies, but different characteristics. They start with a steep slope and indicate that the average acceptance of a post per participant converges over time. Two major differences can be observed. First, after day three, the participants of the TG start to perform better compared to the ones of the CG, i.e., their posts were rated higher, and keep performing better until the end. Second, around day eight the values of the TG increase and the ones of the CG decrease.

Hypothesis Testing. To investigate the significance of the differences between the observed data of the two experiment groups, we tested the corresponding hypothesis with a t-test.

H_0-2: Algorithms mapping the sum of received rating values of posted needs to levels have no influence on the average stakeholder acceptance of posted needs.

The results are summarized in Table 5.4 and further explained below. Regarding the average stakeholder acceptance of posts, the TG (μ=4.3, σ=1.9, n=9) performed better than the CG (μ=1.5, σ=1.7, n=11). Recall that for the participants in the TG the difficulty to reach a competence level rapidly increased up to level three, while for the CG, the difficulty slowly increased up to the same maximum until level four. The result of the t-test is significant at $p \leq 0.05$, thus we can reject our null hypothesis. The effect size for this result is r=0.63 which represents a strong effect. This shows that the significance of our test results is meaningful.

5.6.4 Post-Experiment Survey

After the experiment, we sent an online questionnaire via e-mail to all participants asking them about their attitude towards the experiment and towards the influence of the game elements on their activities. Although they were offered an incentive, only 14 people, seven of each group, answered.

The results are summarized in Fig. 5.6 and Fig. 5.7. To derive the participants' attitudes we followed the idea of semantic differential scales [OST64] with a one-polar scale, i.e., we used single adjectives instead of opposite pairs, where 1 means *not at all* and 7 means *absolutely*.

The results presented in Fig. 5.6 show similar perceptions in the CG and in the TG. The majority in both groups perceived the experiment as fairly interesting and fun, and as rather moderately exhausting and challenging.

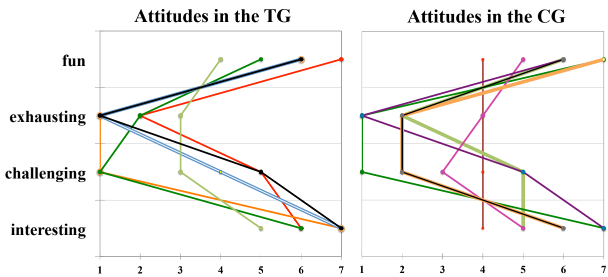


Figure 5.6: Participants' attitudes towards the experiment.

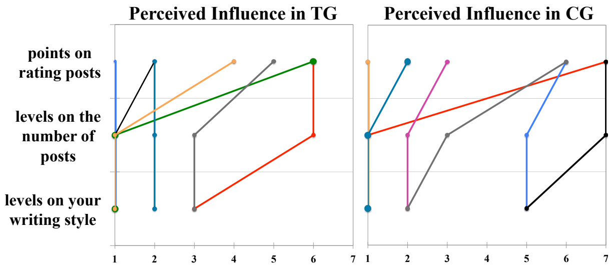


Figure 5.7: Participants' perceived influence of game elements on activities.

The results shown in Fig. 5.7 are inconclusive. In both groups, more participants perceived the influence of points on the rating of posts to be stronger than the influence of the levels on the creation or style of posts. However, for both groups the answers are widely spread.

5.7 Discussion

When revisiting our research questions, we can indeed state that the chosen algorithms do have an influence on the performance of the stakeholders.

5.7.1 Research Questions

RQ1: What is the influence of algorithms calculating the number of points stakeholders get for rating needs posted by others on the engagement of these stakeholders? The results of the *point sub-experiment* show that the way how algorithms calculate points for rating needs has a statistically significant effect on the prioritization process with respect to *stakeholder engagement*. The effect size indicates a medium effect of this result. Moreover, the results demonstrate that the influence was stronger in the treatment group where it was harder for the participants to earn the points than in the control group.

RQ2: How do algorithms mapping the values of the ratings the stakeholders received for their posted needs to levels influence the average stakeholder acceptance of posted needs? The results of the *level sub-experiment* show that the way how algorithms map rating values to levels has a statistically significant effect on the prioritization process with respect to the *stakeholder acceptance* of posted needs (according to the participants' perception). The effect size indicates a strong effect of this result.

The results further demonstrate that the observed influence was stronger in the treatment group, where the difficulty to achieve a level rapidly increased until level three.

5.7.2 Overall Considerations

We found three overall aspects that we briefly discuss below. (1) On average, participants in the TG performed more activities than those in the CG. This result is surprising as the gamification algorithms that we used for the TG require more engagement at an early stage to reach the next goal, i.e., the next level, and the daily points, compared to the algorithms applied in the CG. A possible explanation for this behavior is that the participants of the TG were boosted by the higher challenge. Another explanation could be that the inherent motivation towards the Smart Workout Motivation (SwaWoMo) system was lower in the CG than the one in the TG. For example, four participants of the CG had never performed workouts, while all participants in the TG had. (2) In contrast to the different numbers of performed activities, we observed that the participants' behavior in performing these activities have similar tendencies in both groups over time. A possible reason for this result is that applying the same game element for the same task within the same context may lead to a similar user behavior (which is reflected by the similar graphs). (3) We cannot confirm an influence of weekends (days four to five and eleven to twelve) and holidays (day six) on the results.

For days four to six, the values in the CG are below average, but the ones in the TG are not. On the other hand, the values decrease between days eleven and twelve in both groups. Yet, the latter effect could also be due to the end of the experiment.

The results of the experiment are not clearly supported by the results of the follow-up survey, where we found no major difference with respect to the participants' attitude between the two groups. This contradicts the assumption that participants of the CG were less motivated to participate. Further, the survey results do not show any major difference between the two groups concerning the influence of the game elements. The CG members even perceived a slightly higher influence of the points received for rating than the TG members. This discrepancy between perception and reality might indicate that the participants were not aware of how much they were influenced by the game elements. Further, participation in the follow-up survey was not mandatory and only seven participants of each group completed the questionnaire. The missing results might provide more clarity.

5.8 Threats to validity

We discuss relevant threats to the validity of our experiment according to the categorization by Wohlin et al. [WRH+12].

Internal Validity: We do not regard maturation as a serious threat. With respect to tiredness and boredom, the results of the post-experiment survey show that most of the participants perceived the experiment as interesting and fun. Further, all participants contributed their posts and ratings on the Garuso platform voluntarily.

We do not perceive selection as a major threat. Due to the inherent motivation of volunteers towards the subject of an experiment, it is often believed that they might not represent the general community. However, in the context of stakeholders outside organizational reach, due to not being able to instruct them, this kind of inherent motivation is needed.

We do not consider the random assignment of the participants to the groups as a major threat. We acknowledge that the strength of inherent motivation can vary among the participants. However, motivational intensity is mainly influenced by how autonomy, competence, and relatedness are perceived during an activity or by a reward [RD00]. In this context, we therefore regard the gamification design as more important than the homogeneity of the groups.

External Validity: We do not regard interaction of selection and treatment as a major threat. The effects caused by game elements (and by the algorithm controlling them) depend on the context in which gamification is applied. Therefore, the results of our experiment cannot just be generalized to other application domains. However, due to the experiment design, e.g., popular game elements and activities that typically are performed on a social media platform, we think generalization is possible for most RE activities that involve stakeholders outside organizational reach for collaboration.

We regard interaction of setting and treatment as a minor threat. To be as close to reality as possible, we identified stakeholders outside organizational reach as participants, conducted a field experiment (instead of a laboratory experiment), and applied algorithms that are reasonable in the given context. However, to isolate the dependent variables we inhibited social and normative comparisons, which are regarded as catalysts in gamification. Therefore, our results are preliminary. Further, additional approaches need to be considered to deal with common challenges in RE, e.g., scalability, duplicated posts, and saturation, i.e., the decreasing number of post.

Construct Validity: We addressed mono-operation bias by running two sub-experiments in which we evaluated two independent variables with a treatment and a control group.

We do not consider mono-method bias as a threat since we evaluated the data in different ways, using descriptive statistics, observations, statistical tests and a questionnaire.

We addressed evaluation apprehension, i.e. looking better when being evaluated, by inhibiting comparisons among the participants and by assuring full confidentiality to the participants to prevent evaluation stress.

Conclusion Validity: We addressed violated assumptions of statistical tests by testing the data with respect to normal distribution and variance equality.

We addressed reliability of measures by involving senior researchers from different fields to discuss the experiment design and test the usability of the platform.

We limited the risk of false ratings by allowing participants to change their ratings at any time. Further, we randomized the order of shown posts to prevent that new posts are always shown first.

5.9 Conclusion and Future Work

We report on a between subject field experiment in which we investigated the effects of gamification algorithms on requirements prioritization. Our focus was on the *effects of the algorithms* that control the game elements *points* and *levels* on the *number* and *values* of post ratings on the Garuso platform. The experiment involved 20 stakeholders outside organizational reach over a period of twelve days.

The results show that the algorithms controlling the game elements have a statistically significant influence on the stakeholders outside organizational reach with respect to their contributions to requirements prioritization. We believe that the presented research contributes important knowledge to leveraging the wisdom and creativity of a crowd of stakeholders when prioritizing requirements as well as to the body of gamification principles in the field of RE. Yet, the results are preliminary.

To tap into the predicted high potential of gamification in RE [PGBP15], more research is needed. We encourage researchers to further exploit gamification algorithms with respect to other RE activities and game elements, more participants, and longer periods of time.

In a next step, we are going to apply our findings in the final implementation of the Garuso platform, conduct a real world case study, and evaluate the results with respect to stakeholder participation.

Chapter 6
GARUSO

Original publication:
GARUSO: A Gamification Approach for Involving Stakeholders Outside Organizational Reach in Requirements Engineering
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Submitted to Requirements Engineering Journal (REJ) for publication

Abstract

Stakeholder participation is a key success factor of Requirements Engineering (RE). However, most of the techniques for identifying and involving stakeholders in RE assume that stakeholders can be identified among the members of the organizations involved when a system is ordered, developed, and maintained – and that these stakeholders can be asked or even mandated to contribute. This assumptions no longer hold for many of today's systems where

significant stakeholders (in particular, end-users and people affected by a system) are outside organizational reach*: they are neither known nor can they easily be identified in the involved organizations, nor can they be told to contribute.*

In this context, we developed the GARUSO approach, which uses a social media platform and gamification for attracting stakeholders outside organizational reach and for motivating them to collaboratively contribute to the elicitation and prioritization of requirements.

In this paper, we describe the GARUSO approach and report on its empirical evaluation with a field study of three months. We found that the GARUSO approach works: the platform effectively attracted a crowd of stakeholders outside organizational reach and motivated them to contribute voluntarily to collaborative RE processes. We also derived a first set of design principles about how to involve stakeholders outside organizational reach in RE.

Our work expands the body of knowledge on crowd RE, in paricular on how to deal with stakeholders outside organizational reach.

6.1 Introduction

The success probability of a software system strongly depends on the stakeholders' participation in RE activities [BZ15]. Current RE techniques effectively support the participation of stakeholders in the elicitation and prioritization of requirements for systems or products that are built for a dedicated community of users. The stakeholders of these systems can, typically, be found among the members of the organizations that order or supply the systems or in easily identifiable related organizations such as sub-contractors or regulation agencies. RE experts can identify these so-called stakeholders *within* organizational reach rather straightforwardly, tell them to participate in the elicitation or prioritization of requirements, and instruct them how to do so. Yet, an increasing number of more recent software systems is ubiquitously available and embedded in everyday devices. Many stakeholders of such systems are no members of the organizations that order or supply the system nor of any well-known related organization. We call them *stakeholders outside organizational reach*, hence. For ubiquitously deployed systems, the stakeholders outside organizational reach are likely numerous, highly heterogeneous, and location-independent. Furthermore, they cannot be told to participate but need to be motivated.

Current RE approaches can neither sufficiently identify stakeholders *outside* organizational reach nor facilitate and motivate their collaborative participation in RE activities (see Sect. 6.2).

In our research, we address the challenges of stakeholder identification and participation with respect to stakeholders *outside* organizational reach. We have developed the GARUSO approach, which consists of two parts:

1. A strategy that uses diverse online channels for identifing stakeholders *outside* organizational reach;
2. The GARUSO platform, a social media platform that applies gamification to enable and motivate stakeholders to participate in the collaborative elicitation and prioritization of requirements.

In this article, we present the GARUSO approach and its evaluation. The evaluation results show that the identification strategy attracted 726 visitors from around the world. 244 of them were potential stakeholders. 63 people from this group participated in the collaborative elicitation and prioritization of requirements on the GARUSO platform within a period of three months. Our findings reveal the relevance of continuous stakeholder identification. Furthermore, they show the importance of considering the stakeholders' heterogeneity and experience for the design of the motivation concept used for the gamificiation approach.

We make four contributions. First, we contribute a strategy for identifying stakeholders outside organizational reach based on the results of an explorative study. Second, we provide a comprehensive description of the architecture and the user interface of the GARUSO platform. Third, we empirically demonstrate the effectiveness of the GARUSO approach. Fourth, we derive a first set of design principles for stakeholder identification and participation with respect to stakeholders outside organizational reach.

The remainder of this paper is structured as follows: Section 6.2 gives background information and highlights our motivation. Subsequently, we present our research goal and the research questions in Section 6.3. Section 6.4 investigates the identification of stakeholders outside organizational reach. Section 6.5 presents the GARUSO platform. In Section 6.6 we evaluate the GARUSO approach and report on the results and derive a set of design principles from them. Related work is presented in Section 6.7. Section 6.8 concludes the paper with a summary and outlook.

6.2 Background and Motivation

A successful software system satisfies social and technical requirements [Gog94]. Moreover, it should consider requirements that support sustainable development [LP17]. To meet these success criteria, requirements are not just collected, but elicited and prioritized.

Requirements elicitation is a complex recurrent process of seeking, uncovering, acquiring and elaborating requirements of a software system [ZC05]. Furthermore, RE experts need to prioritize the elicited requirements according to specific criteria to decide which ones to consider [Gli11]. A broad spectrum of RE techniques exist to support these RE activities, yet, they are limited with respect to stakeholders outside organizational reach.

6.2.1 Stakeholders Outside Organizational Reach

Stakeholders outside organizational reach are stakeholders who cannot be found among the members of the organizations that order or supply a software system or in easily identifiable related organizations. They cannot be told to participate in RE activities and, furthermore, are, likely numerous, location independent, and highly heterogeneous.

Typically, ubiquitously available software systems which are embedded in a real-world context have large numbers of stakeholders outside organizational reach. Addressing the needs of these stakeholders is crucial for the success of such systems, particularly when they have the potential for disrupting existing economic or societal structures such as Airbnb or Uber, for example. Failing to engage stakeholders outside organizational reach in RE processes increases the risk of overseeing technological trends, missing valuable knowledge, and losing potential consumers [MP11].

However, most current techniques for stakeholder identification in RE do not address the problem of finding stakeholders outside organizational reach. The StakeSource approach by Lim et al. [LDIF13] uses a technique called snowballing [Goo61], where already identified stakeholders identify further stakeholders. This approach works for stakeholders both inside and outside organizational reach. However, it does not support the identification of initial stakeholders who then will identify new ones.

The problem of selecting representative samples from a target population when conducting opinion polls has similarities to the problem of identifying stakeholders outside organizational reach. However, for stakeholders outside organizational reach, the focus is on finding a large number of heterogeneous stakeholders who can be motivated to participate in a collaborative RE endeavor, rather than on finding some representative sample.

6.2.2 Collaboration and Gamification

Given the ubiquitous and embedded context of these software systems and the fact that stakeholders rarely share the same needs [YWK$^+$08, KSK14], collaborative elicitation techniques are of main interest. In fact, they focus on consensus and stakeholder buy-in [NE00], and support the exploration of so-called green-field domains, which are new domains of great uncertainty [NE00, SS13].

Social media based RE platforms support large-scale collaboration. However, they assume that stakeholders can be told to participate in the platform activities, which is not the case for stakeholders outside organizational reach. Hence, we need a means for motivating stakeholders to participate voluntarily in platform activities. *Gamification* provides such a means.

Gamification is a concept that suggests the use of game-elements such as points or levels in non-game contexts [DDKN11].

Its purpose is to harnesses the motivational power of games and apply it to real-world problems [LH11]. Research results in RE show that gamification has the potential to positively affect the quantity and quality of requirements [FDR+12], support collaboration in group elicitation approaches [SDB+15], and increase the number of creative contributions [LDLB16].

Snijders et al. [SDB+15] describe a social media based RE platform that applies gamification. However, this approach is designed with focus on stakeholders within organizational reach. For example, it does not provide any means to instruct the stakeholders independently of RE experts on how to participate on the platform. Furthermore, the motivation concept behind the gamification approach is not tailored to different personality aspects and as such does not address the high heterogeneity of stakeholders outside organizational reach. For example, while some people are motivated by competitions, others perceive them as stressful and therefore de-motivating and instead prefer collaborations. Therefore, a gamification approach that is designed with focus on stakeholders *within* organizational reach cannot just be re-used as is for motivating stakeholders *outside* organizational reach.

Kankanhalli et al. [KTCK12] state that neglecting how people can be motivated or randomly applying gamification bears the risk of damaging their inherent motivation. This underlines the need for a well-designed motivation concept and suitable algorithms for controlling achievements in gamification such as points or levels.

Kolpondinos and Glinz [HKG17b] have contributed a stakeholder motivation concept for gamification approaches in RE which works in the context of stakeholders outside organizational reach. We use this concept as basis for the gamification engine of the GARUSO platform. They also have investigated the influence of gamification algorithms on the collaborative prioritization of requirements [HKG17a].

6.2.3 The GARUSO Approach

The need to involve stakeholders outside organizational reach as described above motivated us to develop the GARUSO (**G**ame-b**a**sed **R**eq**u**irement**s** Elicitati**o**n) approach. GARUSO consists of two parts: (i) a strategy for identifying stakeholders outside organizational reach, and (ii) a platform on which these stakeholders can participate in the elicitation and prioritization of requirements collaboratively and which uses gamification for motivating them to participate voluntarily.

6.2.4 The SmaWoMo System

For the studies that we conducted to develop and evaluate the GARUSO approach, we needed a software system for which we could identify stakeholders and let them collaboratively support the elicitation and prioritization of requirements on the GARUSO platform.

For this purpose we used a software system which is part of a smart living project on energy efficiency [Emp] at Empa, the Swiss federal research institute for materials science and technology. One of the goals of this project is to transform the mechanical energy generated by people while using workout equipment into electricity. To increase the electricity production, a software system is embedded in the workout equipment to motivate people towards using such enhanced workout equipment. We call it the *Smart Workout Motivation (SmaWoMo)* system in the remainder of this paper. Furthermore, the SmaWoMo system should increase the gym members' understanding of producing electricity by providing fun experiences.

6.3 Research Goal & Research Questions

Our research goal is to develop and evaluate the GARUSO approach with respect to the identification and participation of stakeholders outside organizational reach. To achieve this goal, we address three research questions.

RQ1. *How can we identify stakeholders outside organizational reach over diverse online channels?* Stakeholders outside organizational reach cannot just be identified straightforwardly by RE experts. So we need to create a strategy to identify them.

Therefore, we explored over which online channels and with which distribution and advertising means we can reach stakeholders outside organizational reach among a globally distributed crowd of unknown people. For answering RQ1, we performed an exploratory study (Sect. 6.4).

RQ2. *How can we build a platform that supports the collaborative participation of stakeholders outside organizational reach in eliciting and prioritizing requirements?*

Stakeholders outside organizational reach build a distributed group of people who, in most cases, do not know each other. Hence, a platform is needed where they can meet and collaborate. As these people can neither be told to participate in RE activities nor be instructed on how to participate, the platform must provide mechanisms that motivate the stakeholders to participate voluntarily and explain them how to participate. For answering RQ2, we used a design science approach: we designed the architecture of the GARUSO platform and implemented it prototypically (Sect. 6.5).

RQ3. *How effective is the GARUSO approach in attracting stakeholders outside organizational reach, and supporting the collaborative elicitation and prioritization of requirements by these stakeholders?*

Just building the GARUSO platform is not enough. We need to evaluate how well the GARUSO approach actually works in practice.

For answering RQ3, we performed a field study in the wild: we used the GARUSO stakeholder identification strategy for identifying stakeholders over diverse online channels and studied the activities that were performed on the GARUSO platform (Sect. 6.6).

We concentrated on the effectiveness of the GARUSO platform, answering sub-questions such as: How many identified stakeholders participated on the GARUSO platform? How did they interact on the platform? Over which period of time did they participate? How did they perceive the GARUSO platform?

Evaluating the quality of the elicited requirements is beyond the scope of this paper and is subject to future work.

6.4 Towards a Strategy for Identifying Stakeholders Outside Organizational Reach (RQ1)

In this section, we describe an exploratory study that we conducted to investigate the potential of various online distribution channels with respect to the identification of stakeholders outside organizational reach.

We designed an online questionnaire which we distributed using social network sites (SNSs) as well as online advertising and e-mail distribution. During a trial period of eight months, 544 people visited the questionnaire. 402 of them can be classified as stakeholders outside organizational reach.

6.4.1 Study design

The goal of the study was twofold. Primarily we wanted to explore the suitability of social network sites (SNSs), online advertising and targeted e-mailing for the identification of stakeholders outside organizational reach. Additionally, we developed an approach to segment the community of potential stakeholders according to player types [Bar96, Bar04, Bar05] and wanted to test this approach empirically.

The method we applied was to observe distribution patterns and return rates of an online questionnaire over various online channels.

We created an online questionnaire which elicits requirements for the SmaWoMo System (see Sect. 6.2.4). The questionnaire consists of a total of 21 questions[1]. The questions were re-used from an online survey that we had designed in the framework of a research partnership with Empa, the Swiss Federal Laboratories for Materials Science and Technology.

Technically, the questionnaire was built with Unipark[2] which is an online survey tool. Unipark provides a unique URL per questionnaire that can be customized, enables the surveyees to participate with mobile and desktop devices, and provides multi-language support.

[1] The questionnaire is available under: https://figshare.com/s/4da2e2c4469bc590a97c

[2] https://www.unipark.com/en/

To target stakeholders outside organizational reach, we followed three strategies. (1) We selected a variety of online channels for initial distribution. (2) We targeted the community of potential stakeholders with persona-based advertisements. (3) We enabled further distribution of the questionnaire by snowballing [Goo61].

For every initial distribution channel, we created a copy of the questionnaire with a unique URL. This way we were able to trace every returned questionnaire to the channel where that copy of the questionnaire had been injected initially.

6.4.2 Selection of Online Distribution Channels

To support the identification of stakeholders outside organizational reach with respect to different online media contexts we considered two types of stakeholders: stakeholders who have a direct interest in the software system for which the requirements are elicited and indirect stakeholder. The latter are stakeholders who do not necessarily have a direct interest in the software system for which the requirements are elicited, yet, show an interest in topics related to it [HHG15]. For example, these stakeholders might be curious about the software development or about effects caused by using the software system or have an interest in the software system because of their involvement in similar technologies.

We selected six typical online distribution channels:

- Facebook and Google+ to reach people who are SNS members with a focus on social topics,
- LinkedIn and Xing to reach SNS members with a business focus,
- Google AdWords as a widely used online advertising channel,
- The official e-mail service of our university, where we obtained permission to distribute the questionnaire to about 20.000 students and staff.

6.4.3 Targeting Potential Stakeholders

SNSs, typically, have highly heterogeneous users with different backgrounds. Therefore, we segmented the potential stakeholders with respect to the SmaWoMo system.

Firstly, we used a keyword search to identify groups with the SNSs with a potential interest in the SmaWoMo system. In total, we found 48 groups: 11 on Facebook, 12 on Google+, 13 on LinkedIn, and 12 on Xing.

Secondly, we defined personas to address the challenge of not knowing who the stakeholders outside organizational reach are, and created advertisements based on these personas to address them. We used player types [Bar96, Bar04, Bar05] to define the personas, as they are similar to personality traits (see Sect. 6.5.4). In total, we defined four personas (see Table 6.1), based on the four player types *achiever*, *explorer*, *killer*, and *socializer*.

Table 6.1: The personas we created based on player types to segment the users of SNSs

Persona	Player Type	Age	Description	Inherent Motivation	Stake in SmaWoMo
Giuseppe	Killer	22	Giuseppe finished his apprenticeship a few years ago and just got his bachelor degree in international economics. Next week he starts his first job as a salesman in a company that sells high-end products to an exclusive clientele. He is very eager to get the highest selling ratio among his co-workers in order to quickly move up the corporate ladder. Since he believes that one's appearance plays a key role in personal success, he cares a lot about his body shape.	be the best	gain power and control in business
Zoi	Explorer	35	Zoi has a degree in computer science and works as a senior user experience strategist for a large US company in the entertainment industry. She is curious and open-minded and does neither like monotonous work nor routines. Instead, she prefers to challenge herself to get out of her comfort zone by trying new things and to interact with people of different backgrounds. Due to the high cognitive load and the mostly seated position in her job, she started to work out.	discover new things and people	reach and maintain physical balance
	Socializer				connect and interact with others
Heather	Socializer	55	Heather has her social life in London and works as a CEO of an international high-tech company in Singapore. Due to the responsibilities that come with the job, she meets at least twice a month with the English trade association in London. While she is in London, she visits her friends and family. Keeping a healthy life-work balance is very important to her. Her busy schedule makes this increasingly difficult, however. As most of her friends and family are members of the same gym, she decided to become a member at this gym, too.	connect with family and friends	meet family and friends
Hans	Achiever	65	Hans retired recently. Before, he had worked as a construction worker in the same company for almost 50 years. He is ambitious to be good in what he does and never stops until he reaches his goals. A few months ago, he got interested in alternative ways to produce electricity. So far he has installed a solar panel on the roof of his house. As a next step, he wants to combine it with a small wind turbine. To keep his body fit for the heavy work, he started going to the gym.	master challenges	achieve personal goals outside the gym

Figure 6.1: The online advertisements that we designed with respect to the created personas (see Table 6.1).

The latter is represented by two personas as it is dominant in most people [ZC11].

For each of the personas we created a claim which we combined with an image to create an advertisement. Figure 6.1 visualizes these advertisements.

For the Google AdWords campaign we selected keywords from the keyword idea pool, which lists keywords that are automatically generated by Google AdWords with respect to the text that we used for our advertisement. The keywords included, for example, *electricity generation*, *alternative energies*, *fitness*, *workout*.

With respect to e-mail distribution, we applied for permission to distribute the questionnaire to as many students and academic staff members of our university as possible.

6.4.4 Enabling Snowballing

For reaching further stakeholders by snowballing [Goo61], [LQF10a], we enhanced the questionnaire with share buttons of social media channels that enabled the participants to promote the questionnaire URL on these channels.

6.4.5 Distribution of Information

We created identical copies of the questionnaire with unique URLs for each of our six distribution channels. Distribution took place between May 4 and June 3, 2016.

Table 6.2 shows how we distributed the URLs of the corresponding questionnaire copies to the SNS groups that we had identified before. For each group, we chose the persona-specific advertisement which fitted best for that group. We considered each group only once to limit the risk of being excluded due to the impression of spamming. Additionally, we distributed an advertisement showing a combination of all four advertisements as well as the advertisement for Zoi as a socializer to the public threads of Facebook, Google+, and LinkedIn. As Xing does not allow to post images on the public thread, we used one textual version of the advertisements for the public thread of Xing.

To distribute the questionnaire with Google AdWords, we used the following text: *"Generate Electricity @ The Gym: How much chocolate does your mobile need to run? Discover more."* The total cost for the Google AdWords campaign was about 124 USD.

For e-mail distribution, we obtained permission to distribute the questionnaire to about 20.000 students and staff of our university.

Table 6.2: Distribution of questionnaires to social network groups.

Online Advertisement for Persona	**SNS Context**			
	Social		**Business**	
	Facebook	**Google+**	**LinkedIn**	**Xing**
Giuseppe	1	2	2	2
Zoi (explorer)	4	4	4	3
Zoi (socializer)	2	2	2	2
Heather	2	2	1	1
Hans	2	2	4	4
total	11	12	13	12

We used the following e-mail subject: "*Evaluation of motivational aspects for the generation of electricity at the gym*" and started the e-mail with two questions: *"Where can we as individuals contribute to energy efficiency? How can software systems support and motivate us in doing so? What are the requirements of these software systems?* Furthermore, we described the SmaWoMo system and made clear that the surveyees neither have to be gym members nor to do sport at all. The e-mail was sent with an explicit statement that we had obtained permission to send it and that participation was anonymous.

6.4.6 Metrics and Data Analysis

We ran the study from May 4, 2016 through December 31, 2016. During this time all questionnaire copies were published on the Internet. Unipark stores the questionnaire answers together with meta information such as the time of access and a unique identifier in one data set per user and questionnaire[3]. It applies cookies to identify returning users and redirects them to the last answered question. Thereby it updates the data set that was created at a user's first visit. Due to this process, we consider the number of data sets to be a valid metric for the number of *visitors*. To identify stakeholders of the SmaWoMo system among the visitors, we considered the number of answered questions, as done in previous research on crowdsourcing [IG14].

[3] The data is available under:
https://figshare.com/s/d3abc24c965395abb6fd

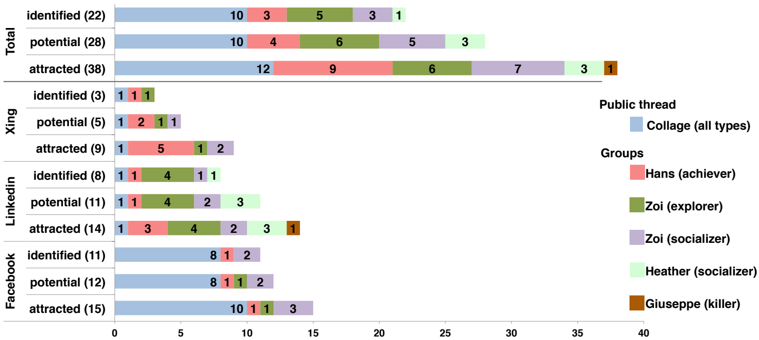
Potential stakeholders are visitors who answered at least the first part of the questionnaire, which includes the introductory and demographic questions. *Stakeholders* are the ones who completed the questionnaire.

To investigate the snowballing approach, we determined how many visitors accessed the questionnaire through a channel which was different from the one where that questionnaire copy had been originally injected by us. We identified the actual access channel by asking the participants in the first question of the questionnaire about the channel where they had found the questionnaire. The channel from which the accessed copy originally came can be traced easily as each of the distributed copies has a unique URL.

6.4.7 Results

In total 544 visitors accessed a questionnaire copies that we had distributed over the online distribution channels mentioned above. 471 answered the initial questions which qualifies them as potential stakeholders according to our definition. 402 people of those 471 completed the questionnaire, which means that we can consider them as stakeholders outside organizational reach. Figure 6.2 shows the results with focus on the SNSs (a) and the other channels that we had used (b).

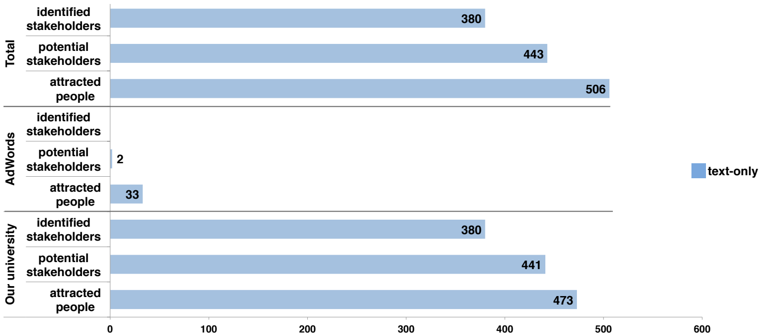
We attracted a surprisingly low number of visitors through SNSs and Google AdWords: 38 and 33, respectively. In contrast, the e-mail distribution yielded 473 visits.



(a) Results per SNS on which we used the persona-based advertisements. Our posts to Google+ resulted in zero visits, hence they are omitted from the figure.

Figure 6.2: Numbers of visitors, potential stakeholders, and identified stakeholders per online channel

With respect to the number of identified stakeholders outside organizational reach, the e-mail distribution was also the most successful one: there, 80% of the visitors completed the questionnaire (which qualifies them as stakeholders outside organizational reach), while only 58% of the visitors of SNSs and zero of the Google AdWord visitors did so. The latter might be due to our very limited budget for the AdWord campaign. When analyzing the results for the SNSs (Fig. 6.2a), we observed major differences in the success of the targeted advertisements in SNS groups and the advertisement on the public threads. For Facebook, the public thread was by far more successful than the groups, while for LinkedIn and Xing it was the opposite.



(b) Results per multi media channel on which we did not use the persona-based advertisements

With respect to the persona-specific advertisements in SNS groups, we observed that the advertisements for Hans (achiever) attracted most people while those for Heather (socializer) and Giuseppe (killer) were rather unsuccessful. The one for Zoi (explorer) identified the highest number stakeholders among the visitors.

Table 6.3 summarizes the results with respect to the snowballing approach.

Table 6.3: Cross-references between channels of access as selected by the surveyees (x-axis) and the initial online channel used for distribution (y-axis) *(visitors; potential stakeholders; identified stakeholders)*

Original distribution channel	Channel of access				
	Facebook	**LinkedIn**	**Google+**	**e-Mail**	**other**
e-mail	5;5;5		1;1;1		2;2;2
LinkedIn				1;1;0	3;0;0
Xing		1;1;1			
AdWords	*3;1;0*	*1;1;0*	*1;0;0*		*1;0;0*

It presents the numbers of cross-references between the involved channels, i.e., how many times a questionnaire copy was accessed from a channel which is different from the one on which we originally distributed the corresponding questionnaire URL. We use semicolons to separate between the results of visitors, potential stakeholders among the visitors, and identified stakeholders among the potential stakeholders, respectively.

6.4.8 Threats to Validity

External Validity. Some recipients of the e-mail might have answered the questionnaire not due to being interested in SmaWoMo, but just in order to support the researchers who had posted the survey. Due to this "courtesy bias", the number of stakeholders observed might be higher than it would be without that influence. However, completing the questionnaire required 20 to 30 minutes. Therefore we think that at least the number of persons who completed the questionnaire and are considered to be stakeholders outside organizational reach for the SmaWoMo system was not biased.

Internal Validity. We could not post every persona-specific advertisemet to exactly the same number of groups on all SNSs. This is due to the fact that (1) we only found a rather limited number of groups related to the topic of SwaWoMo, and (2) we exclusively used one advertisements per SNS group to reduce the risk of being excluded from a group (see Section 6.4.5). This affects the comparability of the numbers found for the different SNSs.

The results on the cross-references depend on how accurate the surveyees' answers were with respect to the online channel through which they accessed the questionnaire. They did, however, not gain anything by giving a faulty answer. Therefore we argue that their self-declaration can be trusted.

6.4.9 Lessons Learned

We considered the results of this study when developing and evaluating the GARUSO approach. We incorporated the following lessons learned into the GARUSO stakeholder identifications strategy with respect to the observation that we made (see Table 6.4): (1) Targeted mass e-mailing is effective and should always be used (O.1). (2) For SNSs, potential stakeholders should be segmented by targeted advertisements and by addressing groups related to the subject of the system for which stakeholders shall be identified. (3) According to O.2, the public thread should be given preference for networks with a social context, while in SNSs with a business focus, groups turned out to be more effective. (4) Concerning segmentation by personas, the achiever type and the explorer types yield best overall results (O.3). (5) Although snowballing turned out to be not very effective, it yields some additional stakeholders (O.4). To enable snowballing, the GARUSO platform provides share buttons for social media channels.

Table 6.4: Summary of observations made

O.1	Targeted mass e-mailing is way more successful in identifying stakeholders outside organizational reach than social networks and online advertising are.
O.2	The identification of stakeholders outside organizational reach over SNS channels is most effective when considering groups for SNSs that focus on business contexts (such as LinkedIn and Xing) and the public threads of the ones with focus on social contexts (such as Facebook).
O.3	The advertisements used on the SNSs yield best overall results with respect to the achiever type and the explorer type.
O.4	The snowballing approach resulted in marginal success. Nevertheless, it identified some stakeholders outside organizational reach who would not have been found otherwise.

6.5 The GARUSO Platform (RQ2)

In this section, we describe the main idea based on which we develop the GARUSO platform and introduce the platform architecture. Subsequently, we explain our visualization scheme and give an example on how to use the GARUSO platform.

6.5.1 Main Idea

The main idea of the GARUSO approach is to support the collaborative participation of stakeholders outside organizational reach in RE activities. For this purpose we developed the GARUSO platform (see Figure 6.3), a social media platform that enables stakeholders to participate collaboratively in activities which support the elicitation and prioritization of requirements. To motivate the stakeholders to participate voluntarily in these activities, we applied gamification.

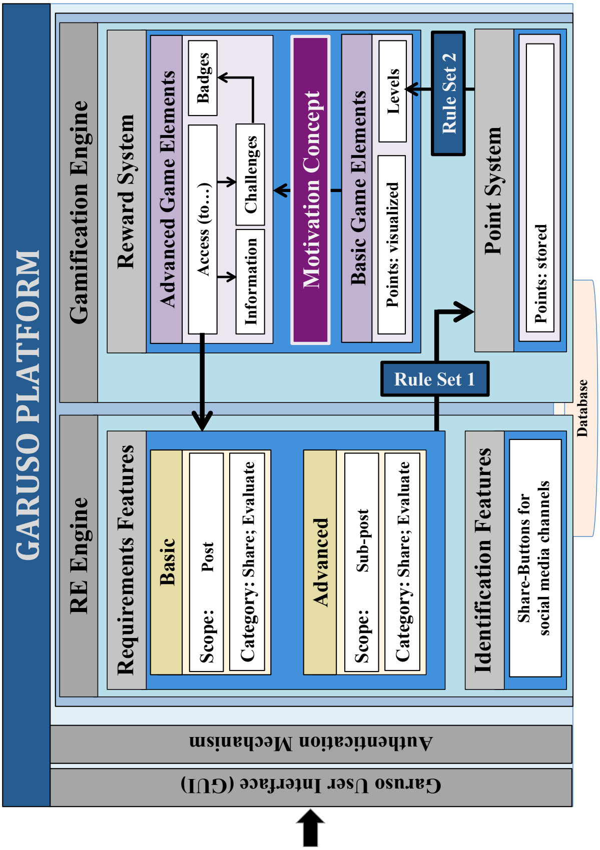


Figure 6.3: The GARUS architecture (adapted after [HKG17a]).

Our gamification approach acknowledges that people cannot just be motivated out of the box. Instead, motivation is, for example, affected by a mix of personality aspects that differ over time. Furthermore, it is a changing state of fluctuating intensity [RD00]. Stakeholder outside organizational reach are likely heterogeneous with respect to various aspects. To be able to motivate them, a gamification approach, therefore, needs to apply a diversified motivation concept. The GARUSO platform provides such a concept.

6.5.2 Overview of the Architecture

Figure 6.3 illustrates the architecture of the GARUSO platform. The *Graphical User Interfact (GUI)* enables visitors to register through the *Authentification Mechanism*. We applied a two-way mechanism to reduce the risk of malicious users. The platform users who successfully registered get access to the features of the *RE Engine* and are motivated by the two systems of the *Gamificiation Engine*. Subsequently, we explain these two engines in more detail.

6.5.3 The RE Engine

The RE Engine has the two components *Requirements Features* and *Identification Features* (see Figure 6.3).

Requirements Features specify the activities that can be taken on the GARUSO platform to support the elicitation and prioritization of requirements. Every activity is defined by one scope and one category each.

- *activity scopes*: post or sub-post
- *activity categories*: share or evaluate

Sharing a post or sub-post means that a stakeholder creates a post or sub-post and, at the same time, shares it with all other users of the GARUSO platform. Stakeholders can *evaluate* other stakeholders' posts by rating posts and voting on claimed benefits. As every post expresses a wish, sharing new posts contributes to the elicitation of new requirements. When evaluating posts or sub-posts, stakeholders provide information on their perception of other stakeholders' requirements, which supports the prioritization process.

Together, a post and its sub-posts build an adapted structure of a user story: *As [role] I want [wish] so that [benefit]*. We choose this approach as user stories contribute to the quality of requirements [LDvdWB15] and support the RE process when involving crowds of stakeholders [DSB$^+$17]. With respect to the GARUSO platform, we simplified the structure, enhanced it with contextual information, and provide a means to extend it. In particular, the platform users can describe a [wish] that they have with respect to the software system for which they participate in the RE activities with a post. Thereby, they also need to add a [benefit] that they assume to experience if the [wish] is fulfilled.

Finally, they need to indicate the context in which they experience this [benefit] most. Figure 6.4 shows a screen shot of the form that has to be completed to share a post on the GARUSO platform. It provides text fields for the [wish] and the [benefit] and labels for the [benefit] context.

Subsequently, we describe the labels that we derived from research on sustainability requirements [HHG15] with an example for the SmaWoMo system, each. (1) *Information*: the [benefit] focuses on facts. For example, it gives information on the number of Watt hours that are produced during a workout session. (2) *Representation*: the [benefit] supports the understanding of sustainability metrics. For example, it shows how many hours a light bulb can be lit with the generated Watt hours. (3) *Comparison*: the [benefit] sets two values in relation to each other. For example, it shows how much electricity a gym member generated compared to the last time or to others. (4) *Select/Define others* enables advanced platform users (see Section 6.5.4) to create a new label and to choose among all created labels. It is replaced by *other than default* for novice users.

To extend the adapted user story and strengthen collaboration, the stakeholders can add sub-posts to a post. A sub-post describes an additional benefit of the wish part of the post to which it is added. Again this benefit requires a benefit label for the context. In summary, together a post and its sub-posts build adapted user stories of the form: *I want [wish] so that [benefit] which contributes most to [label]*, where the part *"so that [benefit] which contributes most to [label]"* can be repeated.

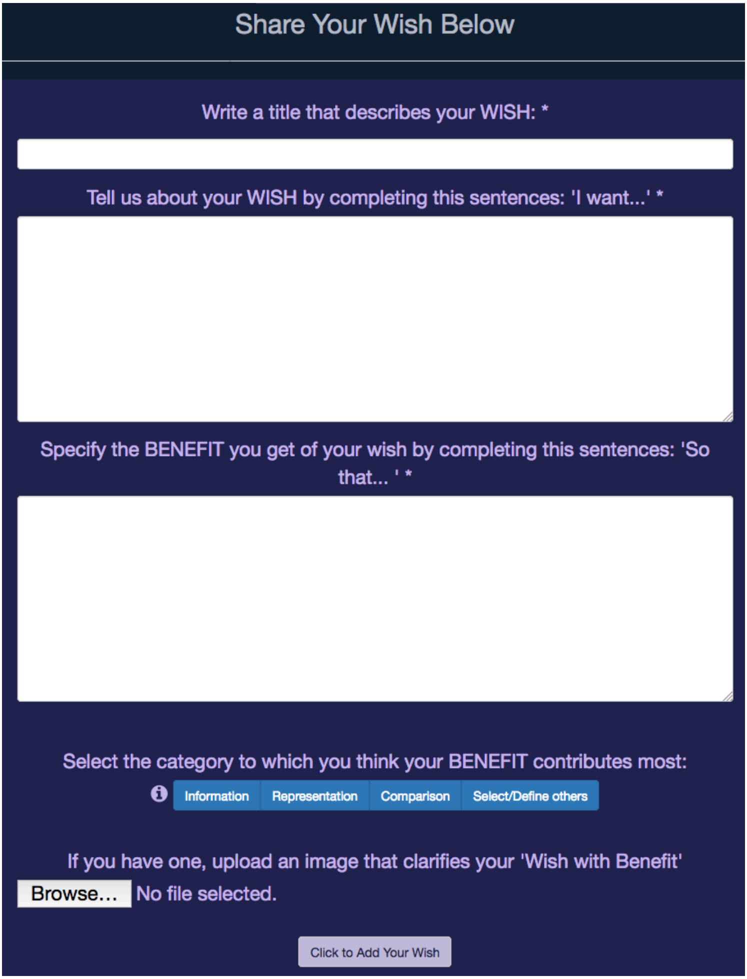


Figure 6.4: Screenshot of the form used on the GARUSO platform to share a post.

With respect to evaluation, stakeholders can *rate* the [wish] part of a post and *vote* on the benefit [label] in a post or sub-post. They can change their evaluation choice at any time, which considers the natural flow of interaction observed in group elicitation methods [NE00]. Stakeholders can also indicate that they do not want to rate or vote a shared contribution.

Identification Features offer a means to identify stakeholders independently of RE experts with share buttons of social media channels. The registered stakeholders can use these buttons to invite other stakeholders over those channels to participate in activities on the GARUSO platform. This approach is inspired by the previously introduced snowballing process [LQF10b].

6.5.4 The Gamification Engine

The *Gamification Engine* consists of two *Rule Sets*, the *Point System* and the *Reward System* (see Figure 6.3).

Rule Set 1 and **Point System:** *Rule Set 1* connects the *Requirement Features* with the *Point System* by translating the stakeholders' activities into points. Table 6.5 illustrates *Rule Set 1*. It shows for every activity that is enabled by the *Requirement Features* the number of points that are *earned* per point category. The point categories mirror the activity categories with *sharing points* and *evaluating points*, and, furthermore, include *community points*.

Table 6.5: Rule Set 1: Earned Points per Activity

Activity	Points to Earn		
	Active		Passive
	sharing points	evaluating points	community points
Share post	6		
Rate post		2	[-2;-1;0;1;2]
Vote post benefit label		2	[-2;0:2]
Share sub-post	3		3
Vote sub-post benefit label		2	[-2;0;2]

- *sharing points:* are the points that a stakeholder earns when sharing a post or sub-post.
- *evaluating points:* are the points that a stakeholder earns when rating or voting an other stakeholder's shared post or sub-post for the first time.
- *community points:* are the points that a stakeholder earns when another stakeholder evaluates one of her shared posts or sub-posts, or adds a sub-post to one of her shared posts.

The number of *sharing points* and *evaluation points* that a stakeholder earns after performing a corresponding activity reflects the effort that we assume is needed to perform the activity. To estimate the effort we set all activities of the same point category in relation to each other. For *sharing points* we assume that to share a post demands the highest effort as it requires two parts of a users story; a wish and its benefit. In contrast, a sub-post only requires a benefit and as such one part of a user story. This is why twice the points are earned for sharing a post compared to sharing a sub-post.

With respect to evaluation, we perceive that to rate a post and to vote on a label of a post or sub-post requires the same effort. Therefore, each of these activities results in the same number of *evaluation points*. It is important to note that *evaluation points* are only earned for the first evaluation of a post or sub-post and not for changing it, which, however, affects the *community points*.

The number of *community points* a stakeholder earns due to the evaluation activity of another stakeholder on own posts and sub-posts reflects the evaluation choices of the other stakeholder. For example, if *stakeholder A* votes for a label of a sub-post shared by *stakeholder B*, *stakeholder B* earns +2 *community points*, whereas a vote against yields -2 and a neutral vote 0 *commmunity points* (in turn *stakeholder A* earns +2 *evaluation points* for the first vote independently of the choice). Compared to voting, rating facilitates a more fine-tuned evaluation with additional values (-1 and +1).

Rule Set 2 connects the *Point System* with the basic game element *level* of the *Reward System*. It defines the number of points *needed* per point category to reach a level. The GARUSO platform uses five levels. They define the stakeholders' expertise with respect to the stakeholders' platform activities from novice (level I) to expert (level V). Figure 6.5 shows for every expertise level (x-axis) the number of needed points (y-axis) per category (curves). For example, to reach level II requires six sharing points, four evaluation points, and one community point. This means, a stakeholder would, for instance, need to share and evaluate at least one post and get one sub-post (see *Rule Set 1*).

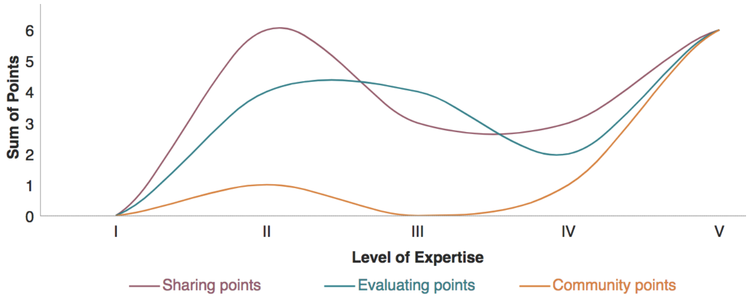
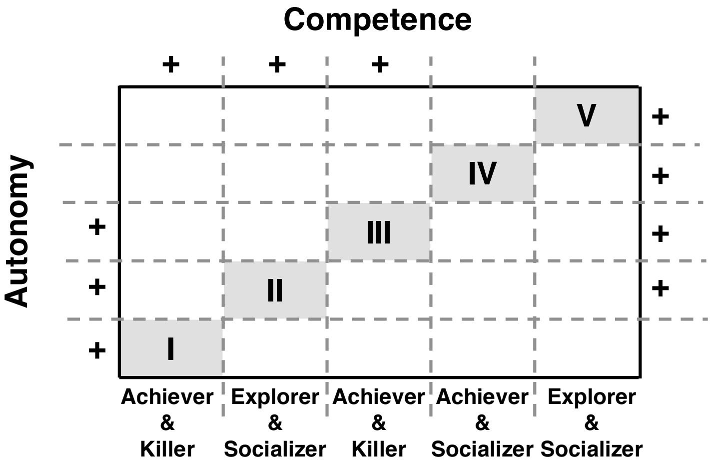


Figure 6.5: Rule Set 2: Needed Points per Level.

The graph increases at the beginning, decreases afterwards and increases again towards the end. This behavior derives from the findings of Kolpondinos and Glinz [HKG17a] on the effects of gamificiation algorithms in RE.

Reward System and **Motivation Concept:** With the *Reward System* we consider the high heterogeneity of stakeholders outside organizational reach when motivating them during their participation on the GARUSO platform. Thereby, the *Motivation Concept* is the core component of the system. It is built upon the stakeholder-centric motivation concept by Kolpondinos and Glinz [HKG17b], which in turn is inspired by the experiential learning theory of Kolb [Kol84]. The latter is a holistic learning theory that reflects the relationship between a person and the environment with the dual meaning of experience ([Kol84, p. 35]):



(a) Motivation Concept (adapted after [HKG17b]).

Figure 6.6: (a) Motivation Concept with indicated rewards (gray area) per expertise level (I to V), player type (bottom line) and basic human needs (autonomy, competence, relatedness) where marked with +

- *The environmental meaning of experience:* "20 years of experience in the job"
- *The personal meaning of experience:* "experiencing joy and happiness"

The purpose of the *Motivation Concept* is to define the rewards of the GARUSO platform with respect to the stakeholders' experience. To measure the stakeholders' experience we use the above described expertise levels. Furthermore, we consider the theory of skill acquisition [DD80], player types [Bar96], and the theory of basic human needs [RD00].

Level	Rewards				
	Non-Game Context	Hybrid Context*		Game Context	
	Requirements Features	Access to Information	Access to Meta-data	Access to Challenges	Badges
V	• Create labels		• Become a chat member		
IV		• Number of users per level • Total evaluation value per post	• Nickname of author per sub-post		
III	• Vote sub-post labels	• Number of voted sub-post labels • Vote values per sub-post label • Vote value per post label	• Nickname of author per post	• Advanced challenges	• Advanced badges
II	• Share sub-posts • Vote post labels	• Number of shared sub-post • Number of voted post labels • Date when a post was shared • Number of sub-posts per post		• Basic challenges	• Basic badges
I	• Share posts • Rate posts	• Number of shared posts • Number of rated posts • Number of users on lower and upper levels			

* We consider this a hybrid context as the rewards themselves refer to the non-game context of RE, yet, they do not directly contribute to the RE activities. Instead, they address motivational aspects, which are related to the game context.

(b) Actual rewards per expertise level.

Figure 6.6: (b) actual rewards of the GARUSO platform based on the Motivation Concept.

Next, we show a short example on how the *Motivation Concept* works, followed by an overview of the most important design considerations.

Figure 6.6a sketches the *Motivation Concept*. It indicates the rewards (gray areas) per expertise level (roman letters), under consideration of the most dominant player types (bottom line) and the basic human needs (side lines and top line) where marked with +. Based on the *Motivation Concept*, Figure 6.6b shows the actual rewards of the GARUSO platform. For example, rewards on level II focus on the explorer and the socializer player types, and consider all three basic human needs (see Figure 6.6a).

Access to basic challenges and information on the publication date of posts address the player types respectively. Furthermore, the two introduced *Requirements Features* address the feeling of autonomy and competence, and numbers on overall activities add to the feeling of relatedness.

The rewards of the non-game context relate to the environmental meaning of experience as they reflect the RE activities. With respect to the skill acquisition theory by Dreyfus [DD80], these rewards focus on the first three expertise levels. The theory states that when people follow the desire to acquire new abilities, they typically pass five stages. Understanding of the domain happens in the third stage. With the rewards of the game context we consider the personal meaning of experience. Furthermore, the hybrid context includes rewards of the non-game context without directly affecting it and address motivational aspects of the game context. Hence, these rewards relate to both meanings of experience. For example, revealing the authors' nicknames give information that considers the RE context and facilitates comparison, which has a high motivational potential.

All rewards are tailored to the four player types by Bartle [Bar96]. *Achievers* prefer to act in the world (or system), while *killers* act on other players. *Socializers* rather interact with players, while *explorers* interact with the world (or system). Thereby, we respect personality traits, which are characteristics of people that define how they act within the social world [Bro94]. In fact, player types are considered the same construct as personality traits, yet, in a different context [FWG13].

When people act in the "real" world, they typically have one dominant personality trait together with several latent ones [TWD+16] of different intensities [FWG13]. Research results show that this is the same with their player types [TWD+16, FWG13, HK14, Mar15]. As people get to know and better understand the virtual environment [Bar05] or system that applies gamification [Mar15], their player types evolve. Therefore, we use the two main player type development paths by Bartle [Bar04] to define the dominant player types per expertise level.

To limit the risk that the stakeholders feel manipulated by the rewards, we considered the theory of basic human needs by Ryan & Deci [RD00], which refer to the feelings of *autonomy* (being in charge); *competence*, (power of free choice); *relatedness*, (being connected with others). Furthermore, we referred to the theory of Maslow's Hierarchy of Needs [Mas43] to decide on which expertise level to focus on these needs.

6.5.5 The GARUSO User Interface (GUI)

Figures 6.7 and 6.8 show a screenshot of the main page and the detailed page of a post on the GARUSO platform. We added roman letters to show the expertise level on which (depending on the previously introduced *Motivation Concept*) the GUI elements become visible.

Figure 6.7: A screenshot of the main page of the GARUSO platform in which we indicate the expertise level (I - III) on which a GUI element becomes visible with roman letters.

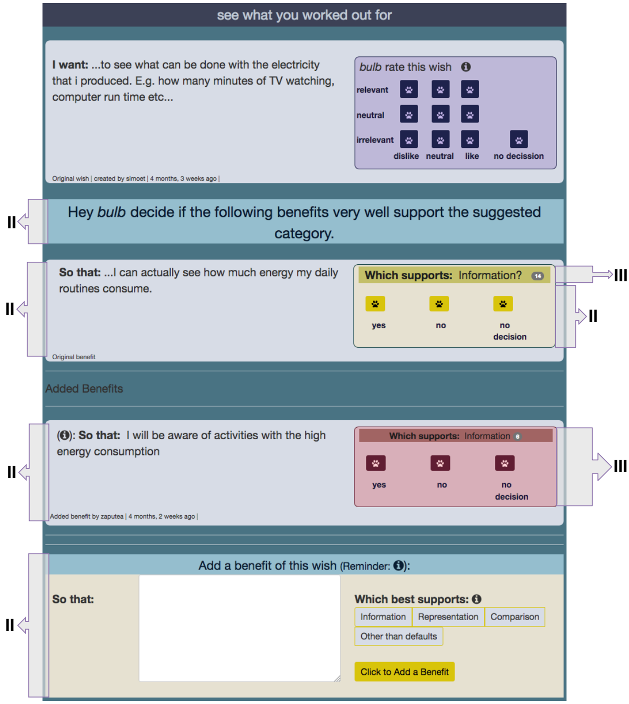


Figure 6.8: A screenshot of the detailed view of a post on the GARUSO platform with the wish-part of the post on top followed by its benefit-part and a sub-post. Again, the roman letters indicate the expertise level on which a GUI element becomes visible.

Due to space considerations we only show the sidebars and the top-navigation bar in the screenshot displayed in Figure 6.7. They exist, however, also in the screenshot shown in Figure 6.8. Next, we describe the visualization scheme that we used for the GUI and give an example to introduce the two pages.

6.5.6 The Visualization Scheme

We created a visualization scheme to distinguish the GUI elements related to single activities facilitated by the *Requirements Features*. Therefore, we considered the activity category and scope (see Figure 6.9).

- *Icons* indicate the activity categories. A *wand* relates to sharing activities as the sharing of posts and sub-post considers a stakeholder's wish. A *paw* represents evaluating activities as they require the click on a button. Furthermore, a *crowd* refers to activities of others for own contributions.
- *Colors* consider the activity scopes. *Violet* refers to activities that directly affect a post such as rating. *Yellow* considers activities that indirectly affect a post such as evaluating its benefit part or sharing a sub-post. *Red* indicates activities that affect a sub-post such as its evaluation. Any other color used in the GUI has no semantic meaning.

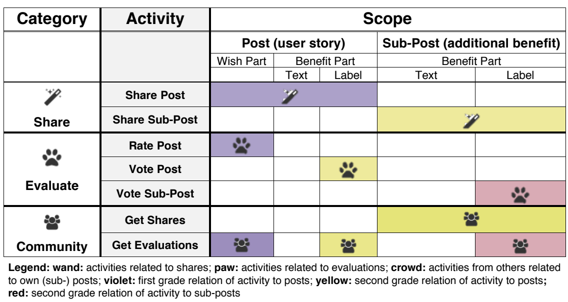


Figure 6.9: Visualization scheme with icons and colors.

6.5.7 Example

After stakeholder *bulb* logged in to the GARUSO platform she is directed to the main page (see Figure 6.7). The top navigation bar enables her to access all other pages of the GARUSO platform, to translate the page content in another language, and to log out. Furthermore, she can support the identification of unidentified stakeholders with the share buttons of the social media channels, which are displayed on the right. With respect to activities facilitated by the *Requirements Features*, she sees her missions in the left sidebar and her status in the right sidebar. The center part of the main page shows the posts in the upper part with statistical information below. The information on her missions shows that she needs, for example, four additional evaluation points to reach level V. As the paw icon is on a green background she can earn them with any evaluation activity, which supports her autonomy. Right below she sees the activities needed to master the basic challenge, which she selected. The wand icon on purple background shows that 18 sharing points are needed due to the explicit sharing of posts. With this specification, *challenges* focus on achiever and explorer player types. *bulb* can also select an advanced challenge, which she has not done, yet. According to her status information she earned 30 community points and three badges among which two were also earned by 13 other stakeholders. Between the sidebars the statistics reveal that the other stakeholders are on average more active except for evaluation activities, and that two of them are on her expertise level. Right above are two carousels.

The upper one shows truncated versions of posts in groups of three and the lower one additionally displays posts with images in groups of four. *bulb* can switch back and forth the carousels with the arrows to the sides. The buttons above enable her to filter the carousel entries. For example, a click on the yellow *voted* button will limit the entries to posts, which have sub-post that she already voted. When she clicks on a carousel entry she gets to the detailed view of a post (see Figure 6.8). The wish-part and the benefit-part of the post are split and followed by a lists of sub-posts. The shown post has one sub-post. Here, *bulb* can evaluate the shared contributions and share additional sub-posts, which she has not done, yet.

6.5.8 Implementation

The GARUSO platform facilitates device independent, multi-language, asynchronous communication among its users. We developed a responsive design that considers the screen size of the accessing device to support desktop and mobile devices alike and applied Google Translate[4] to support multiple languages. On social media platforms, content that is shown at the beginning of a list typically gets the most attention by the users. To address this fact, we developed an automated process that randomly orders the list of posts over time. The features of the *RE Engine* can be used simultaneously and asynchronously by the stakeholders.

[4] https://translate.google.com/

To prevent inconsistent states of existing ratings and votes, already shared (sub-) posts cannot be edited or deleted, which furthermore prevents cheating.

To introduce the platform features to the stakeholders, we followed the strategy of onboarding. Onboarding is, typically, applied in game design and means to make users gradually familiar with the features of a game. We used expertise levels to steer the introduction of the *Requirements Features* and the completion of the GUI. For further support, the platform provides (1) short information on the GUI elements when moving the mouse pointer over them or when tapping on them on mobile devices; (2) an FAQ page; (3) a contact form to get in touch with the administrator.

The GARUSO platform has been implemented with Python 3.4 and the database PostgreSQL 9.4. For the Web framework we considered Django 1.8 [5] as well as Bootstrap 3.3 [6]. Furthermore, we used FontAwsome [7] for the GUI icons and ShareThis[8] for the social media share buttons.

[5] https://www.djangoproject.com/
[6] https://getbootstrap.com/
[7] http://fontawesome.io/
[8] https://www.sharethis.com/

6.6 Evaluation of the GARUSO Approach (RQ3)

So far, we explored how stakeholders outside organizational reach can be identified (see Sect. 6.4) and built the GARUSO platform with a design science approach (see Sect. 6.5). Next, we wanted to evaluate the overall GARUSO approach. Therefore, we conducted an empirical study of 92 days in the wild. The software system for which the platform users participated in the elicitation and prioritization of requirements, was the SmaWoMo system that we described in Section 6.2.4.

The study results contribute valuable insights in the domain of crowd RE with focus on the identification and participation of stakeholders outside organizational reach. With the identification strategy we attracted 728 visitors from around the world to the GARUSO platform of whom 244 are considered potential stakeholders and 63 stakeholders. During the study period the stakeholders participated on 49 days on the GARUSO platform during which they conducted a total of 504 activities related to requirements elicitation and prioritization.

6.6.1 Study Design

We ran the study for 92 days from September 2, 2017 through December 2, 2017.

The platform was online available over the entire 92 days during which visitors could register and consecutively participate in the platform activities. Until day 47 we occasionally injected information. The corresponding activities are summarized in chronological order in Table 6.6 and described next.

The study started when the first author of this article shared three initial posts on the GARUSO platform. To identify stakeholders of the SmaWoMo system and attract them to the GARUSO platform, we considered the lessons we learned in the study on stakeholder identification (see Sect. 6.4.9). We used the SNSs Facebook, LinkedIn, and Xing, and considered the online advertisement channel Google Adwords, as well as the e-mail list used in the study described in Sect. 6.4, an e-mail list on ICT and sustainability, and the Empa intranet. Furthermore, we used the advertisements of Hans (achiever) and Zoi (explorer).

We distributed the advertisements in total eleven times on Facebook, eight times on LinkedIn and seven times on Xing between day six and 14, and again one time on day 40 on Facebook and LinkedIn. On day 12, an e-mail with information on the elicitation of requirements for SmaWoMo on the GARUSO platform was distributed through the official mailing service to about 26'000 students and staff of our university. We started our AdWords Campaign on day 17 with a budget of 80 USD. Furthermore, we accepted the offer of an administrator of a newsletter on different topics on "ICT and sustainability" who asked if we would like to announce our study in the next newsletter feed. The newsletter was sent on day 19 to the about 380 subscribers.

Table 6.6: The interactions we took during the study

Day	Date	Interaction
1	Sept. 2, 2017	Study start
6	Sept. 7, 2017	Advertisement published one time on Facebook (public thread)
7	Sept. 8, 2017	Empa published an advertisement on its intranet
10	Sept. 11, 2017	Advertisement published eight times on Facebook (one time on public thread; seven times in groups)
11	Sept. 12, 2017	Advertisement published one time on Facebook (in group)
12	Sept. 13, 2017	Advertisement published one time on Facebook (on public thread) and e-mail sent to students and staff of our university
13	Sept. 14, 2017	Advertisement published three times on LinkedIn (in groups) and seven times on Xing (in groups)
14	Sept. 15, 2017	Advertisement published five times on LinkedIn (one time on public thread; four times in groups) and information e-mail no. 1 sent to platform users
17	Sept. 18, 2017	Started AdWords campaign
18	Sept. 19, 2017	Information e-mail no. 2 sent to platform users
19	Sept. 20, 2017	Information distributed to subscribers of a newsletter on sustainability
25	Sept. 26, 2017	Information e-mail no. 3 sent to platform users
31	Oct. 2, 2017	Information e-mail no. 4 sent to platform users
40	Oct. 11, 2017	Advertisement published one time on Facebook (on public thread) and one time on LinkedIn (public thread), and information e-mail no. 5 sent to platform users
47	Oct. 18, 2017	Information e-mail no. 6 sent to platform users
92	Dec. 2, 2017	Study end

Furthermore, we kept the stakeholders who participated on the GARUSO platform informed about the overall platform activities. This approach is typically applied with automated processes by service providers to keep their customers in the loop.

The GARUSO platform is, however, a prototype, which is why we did not implement such a service but manually distributed e-mails. We sent a total of six notification e-mails to the registered platform users.

Every e-mail summarized the activities of the week and compared them with the ones of the previous week. For example, they included information on the numbers of new registrations and shared (sub-) posts. In the e-mails we also invited the users to further participate on the GARUSO platform. Yet, we never coerced them nor offered them any incentives other than the ones they got from the *Gamification Engine* of the GARUSO platform (see Sect. 6.5.4).

To reduce the risk of malicious and fake users such as bots we applied a two-way and three step registration process: the visitors needed to: (1) provide a nickname and their e-mail address; (2) activate their registration with the link sent to the provided address; (3) create a user profile on the GARUSO platform by answering questions such as about their age and the online channel through which they first accessed the GARUSO platform. All answers were voluntary except the one about the initial access channel. Only the visitors who completed these three steps were enabled to participate in the RE activities on the GARUSO platform.

At this point the platform users were, however, not familiar with the platform features, which bears the risk to overwhelm them.

Overwhelmed users tend to quit or to be unaware of the full potential of a tool. Therefore, only the users who had shared and rated at least one post each saw the GUI as it was designed for user of expertise level I. For the others, the main page (see Figure 6.7) and the detailed page (see Figure 6.8) only displayed elements that focus on the RE activities that are enabled on these pages with information on how to use them. In particular, the main page was limited to the share button and the overview of the posts. Similarly, the detail page only showed the content of the post and the rating scheme. The left sidebar and the information on the statistics at the lower part of the main page appeared after sharing the first post and the right sidebar became visible after rating the first post.

This step-wise process is known as onboarding and typically used in game design and gamification as strategy to make novice player gradually familiar with a system [ZC11].

6.6.2 Metrics & Data Analysis

To be able to evaluated our approach we monitored the data over the entire duration of the study. We tracked the visits to the GARUSO platform with Google Analytics[9] and the activities of registered users on the GARUSO platform with algorithms that we developed. The data was stored by Google and in a local database maintained by the authors. We used both data sets for subsequent analysis[10].

[9] https://analytics.google.com

[10] The data is available under:
https://figshare.com/s/00cd571cf8cd67a207fb

To evaluate the results we applied the following metrics.

1. **Visitor involvement:** To define how involved the platform visitors' are with respect to the RE process for the SmaWoMo system, we measured the frequency and time during which the visitors interacted with the platform. With respect to previous research [RP04], which found that people need ten seconds to be convinced to remain on a Website, we defined visitor involvement as follows:
   lowly involved visitors are visitors who interacted less then 10 seconds with the platform;
   moderately involved visitors are one-time visitors who interacted 10 or more seconds;
   highly involved visitors are returning visitors who interacted more than 10 seconds.
   To know the visitor involvement supports the evaluation of the identification strategy.
2. **Stakeholders:** People or organizations who influence a software system or who are influenced by it are referred to as stakeholders[GW07].
   In a traditional RE context stakeholders are considered within organizational reach. Due to the known roles of people and organizations in the development process of a software system, these stakeholders can be identified rather straightforwardly.
   When it comes to stakeholders outside organizational reach, these roles are, however, rarely known in advance. The question, therefore, is how we know whether a person or organization is a stakeholder outside organizational reach.

We do not know for sure, however, we can develop metrics that support the identification of stakeholders in this context. With respect to the GARUSO approach, this metric is defined by the registration process. Thereby, we assume that due to the invested time and provided personal information required by this process (see Section 6.6.1) the platform visitors who registered on the GARUSO platform are notably interested in the SmaWoMo system and therefore can be considered as stakeholders.

The number of stakeholders helps us to furthermore understand the effectiveness of the identification strategy.

3. **Conversion rate of participating stakeholders:** We define this metric as the fraction of registered platform users who conducted at least one activity on the GARUSO platform that supports the RE activities. Thereby, we are consistent with previous research [IG14] that considers users engaged if they take at least one context-related activity.

   The conversion rate of participating stakeholders adds valuable insights to better assess the design choices of the onboarding process.
4. **Stakeholder participation:** To measure this metric we count the RE activities on the GARUSO platform and consider the number of days during which the activities were taken.

   The stakeholder participation provides a means to investigate the effectiveness of the GARUSO platform with respect to the motivation concept.

We analyze the data in four ways:

(1) To evaluate the identification strategy, we used the information tracked with Google Analytics that we first cleaned from spam and bot entries with features provided by Google Analytics. Consecutively, we selected the filter criteria *new users*, which in Google Analytics describes first-time users, and *session*, which defines user interactions, such as, page views on the monitored website within a time-frame. To set the time-frame we used the metric on stakeholder involvement that we described above. For example, to calculate the number of visitors with low involvement, we looked for new uses who had one or multiple sessions, with each a duration of less than 10 seconds (see Table 6.7 and Figure 6.10). Google Analytics monitors, however, traffic sources. Based on their definitions[11] we map them to the online channels used in our identification strategy (see Figure 6.10c and 6.11).

- **Mapping 1:** access through the distribution by e-mail is included in direct traffic.
- **Mapping 2:** access through our Google AdWords campaign is included in traffic from display networks[12] and paid search.
- **Mapping 3:** access through the Empa intranet is included in traffic from referrals.

(2) With focus on stakeholders, we calculated the number of those who actively participated in the RE activities on the GARUSO platform (see Table 6.8) and considered the data they provided during their registration process to investigate demographic aspects (see Table 6.9) and their domain knowledge (see Figure 6.12).

[11] https://support.google.com/analytics/answer/6205762
[12] https://support.google.com/adwords/answer/2404190

(3) In terms of stakeholder participation, we plotted the values of the platform activities for the entire time of the study (see Figure 6.13) and analyzed them with respect to the stakeholders' login activities (see Table 6.10) and RE activities (see Table 6.11).

(4) We complete the analysis on the stakeholders' participation with the evaluation of their feedback (see Figure 6.14 and Figure 6.15).

6.6.3 Results

In this subsection we present the results of our evaluation of the GARUSO approach and report on the key findings. Therefore, we grouped the findings according to four major aspects: stakeholder identification, stakeholder characteristics, stakeholder participation, and stakeholder feedback.

Key Findings on Stakeholder Identification (SI)

In the following, we present and discuss four key findings on the effectiveness of the identification strategy.

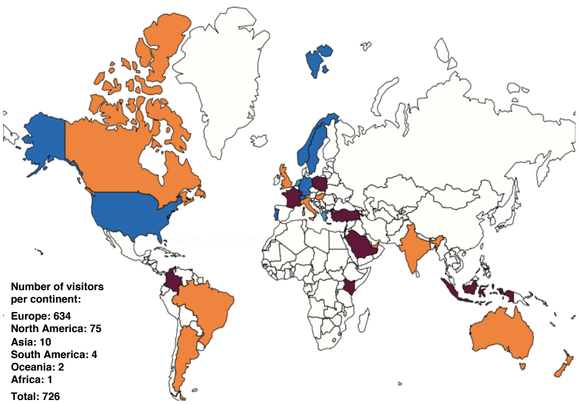
Table 6.7: Summary of the platform visitors' involvement

		726 (100%)
platform visitors	with low involvement	482 (66.39%)
	with moderate involvement	175 (24.10%)
	with high involvement	69 (9.50%)

KF_SI 1: Every third visitor is a potential stakeholder. Table 6.7 presents the results based on the metric on user involvement. It reveals that, overall, the GARUSO platform had 726 individual visitors. 482 (66.39%) of them had a low involvement compared to 244 (33.61%) of whom 175 (24.10%) were moderately involved and 69 (9.50%) highly involved. We regard the latter two as potential stakeholder of the SmaWoMo system.

Discussion: Any visitor of the GARUSO platform who registered on the platform is considered a stakeholder for SmaWoMo (see Section 6.6.2). Taking the metric of visitor involvement into account, it becomes clear that *lowly involved visitors* had not the time to register on the platform. Therefore, we do not refer to them as potential stakeholders for SmaWoMo. In fact, it is rather likely that they clicked on the link to the GARUSO platform because they expected different content. In contrast, *moderately involved visitors* as well as *highly involved visitors* had the time to register on the GARUSO platform. However, the data does not reveal whether they actually did so. Thus, they might also have quit or started the registration process without completing it, for example, because they were interrupted or could not spend the entire time needed to complete it. Either way, their level of involvement indicates that they had some interest for SmaWoMo. We, therefore, consider them potential stakeholders. In summary, the data shows that one third of all visitors (33.61%) are potential stakeholders for SmaWoMo. This result is consistent with previous research results [IG14] on crowdsourcing, which considered 34.6% of all website visitors who were attracted with online advertisements engaged.

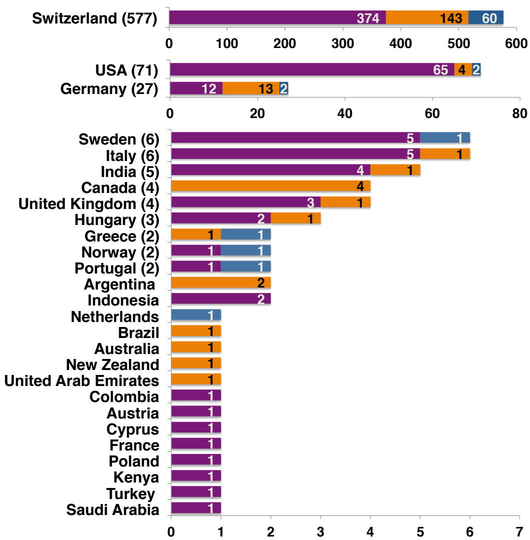
KF_SI 2: The visitors accessed across all continents with regional differences. Figure 6.10a and Figure 6.10b illustrate from where the GARUSO platform was accessed. The results show that the visitors accessed from 27 countries around the globe and across all continents, but with regional differences. In fact, 97.66% (709) of all visitors accessed the GARUSO platform from countries in Europe and North America. With 577 visitors (79.48%) the majority accessed from Switzerland followed by the US with 71 (9.78%) visitors, and Germany with 27 (3.72%). In contrast, only one visitor (0.14%) accessed from an African country.



(a) Countries from where visitors accessed with respect to the maximum level of involvement

Figure 6.10: Illustration on the visitors of the GARUSO platform with respect to their level of involvement.

Discussion: The results can partially be explained with digital inequality. In fact, a study on global Internet access [Pou16] shows that people have global access to the Internet but with regional differences. For example, only about 25% of people living in African countries have Internet access, which makes it the only continent where less than 50% of the population have Internet access. In contrast, 89% and 80% of people in North America and Europe have Internet access respectively. Digital inequality can, however, not explain all our results. For example, in China the Internet access rate is 65%, yet, no visitor accessed the GARUSO platform from there.

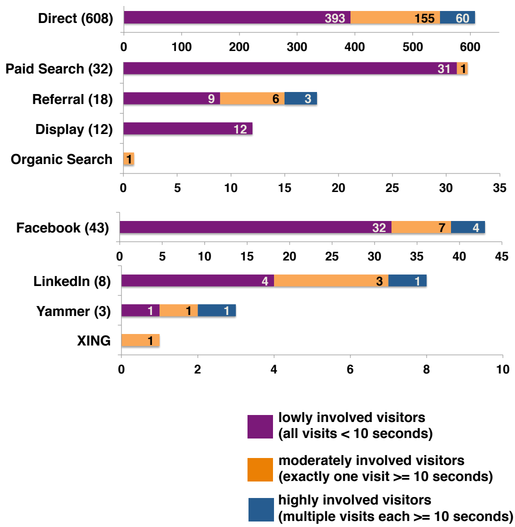


(b) Number of visitors per country and level of involvement

This result is most likely influenced by the internet censorship of the Chinese government, which blocks the access to SNSs like Facebook [FCC13]. Similarly, countries like North Korea and Cuba restrict the Internet access of their citizens [Ios11]. Moreover, previous research indicates that the size of individual networks on SNS differs across cultures [KSC11]. This suggests that the online channels, which we used for the purpose of stakeholder identification, affect our results in terms of countries of access. With respect to Switzerland, which is an outlier considering the number of visitors, the results are probably influenced to some extent by the fact that the SmaWoMo project is conducted in Switzerland and both our university and Empa are Swiss research institutions. Moreover, the stakeholder identification was initiated in Switzerland, which is potentially important to consider as SNS algorithms, typically, decide what information their members get to see and as such influence their members activities. For example, Facebook regards its users as consumers and targets them accordingly [Val12]. Due to these marketing considerations, it is likely that in the context of our study the SNSs rather focused on members located in Switzerland.

The studies to which we referred above can, however, not explain all our results. For example, India has a low Internet access rate of 22%. Yet, it is the country with the sixth highest number of visitors of all 27 countries of access, which is consistent with results of different studies on the demographics of Mechanical Turk [PC14, Ipe10, PCI10],. In those studies around 40% of all participants came from India.

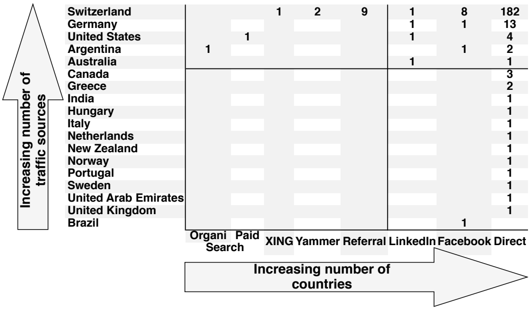
KF_SI 3: The largest sources of access are not the most effective ones with respect to potential stakeholders. Figure 6.10b and Figure 6.10c illustrate the countries from where the GARUSO platform was accessed and the traffic sources that were used for the access. The results show that 93% (675) of the visitors accessed the GARUSO platform from the only three countries with more than 26 visitors: Switzerland, the US, and Germany; Furthermore, 94.08% (683) of all visitors accessed through one of the three only traffic sources with more than 31 visitors: direct traffic, Facebook, and paid search results. Yet, the results indicate that neither of these countries or traffic sources are among the most effective ones with respect to the identification of potential stakeholders.



(c) Number of visitors per traffic source and level of involvement

Discussion: Overall, more than 90% of the visitors accessed the GARUSO platform through only three sources with respect to countries and traffic channels. This suggests that the efficiency of the identification strategy can be increased by focusing on a few countries and online channels. This assumption is, however, rebutted when considering the visitors' level of involvement. In fact, the countries with the highest numbers of visitors provide a rather small share of potential stakeholders. In contrast, eight different countries have smaller numbers of visitors: Canada, Argentina, Greece, the Netherlands, Brazil, Australia, New Zealand, and the United Arab Emirates. The visitors from those countries are, however, all potential stakeholders. Similarly, the online channels with the highest share of potential stakeholders were used by a smaller number of visitors: Xing, organic search, referrals, and LinkedIn.

KF_SI 4: The variety of online channels enhanced the RE process. Figure 6.11 shows the number of visiting potential stakeholders under consideration of the traffic sources (x-axis) and the countries of access (y-axis). The further away a source or country is from the intersection of the two axes the more relevant it becomes with respect to the other axis. For example, the right most traffic source (direct traffic) was used in most countries (16 of 18), and most traffic sources (six of eight) were used in the country on top (Switzerland). The results in the right part reveal that only three traffic sources (LinkedIn to Direct traffic) were used in more than one country. Similarly, the ones in the upper part show that only in five countries (Austria to Switzerland) more than one traffic source was used. With respect to the mapping



	Organi Search	Paid Search	XING	Yammer	Referral	LinkedIn	Facebook	Direct
Switzerland			1	2	9	1	8	182
Germany						1	1	13
United States		1				1		4
Argentina	1						1	2
Australia						1		1
Canada								3
Greece								2
India								1
Hungary								1
Italy								1
Netherlands								1
New Zealand								1
Norway								1
Portugal								1
Sweden								1
United Arab Emirates								1
United Kingdom								1
Brazil							1	

Figure 6.11: Number of visiting potential stakeholders per country of access and used traffic source.

between the initially used online channels and the traffic sources (see Section 6.6.2), the results suggest that a few channels suffice to identify stakeholders outside organizational reach.

Discussion: Previous research results indicate that online communities reflect their members' everyday life in the physical world, which limits interactions across online communities [Har07]. In particular, these results show that the members of different SNSs are heterogeneous across the SNSs in terms of demographic characteristics and social surroundings such as their race and living situation [Har07], as well as their age, education, income, and urbanity [DB13]. In contrast, the countries of access do not necessarily reveal any information on the visitors' backgrounds, yet, the give contextual information. This information is relevant during RE processes as it can affect the design and behavior of a software system [FFGSP10], provide objective information that completes subjective needs [FCC+07], and support the analysis of requirements [SFS06].

Thus, the results presented in Figure 6.11 in fact highlight the benefit of using a variety of initial online distribution channels to identify stakeholders outside organizational reach with respect to heterogeneity aspects and contextual information.

Key Findings on the Active Stakeholders' Characteristics (SC)

Next, we present and discuss two key findings about the active stakeholders of the SmaWoMo system.

KF_SC 1: Overall, stakeholder participation is above average. Table 6.8 reveals that 63 stakeholders were identified, which means that about every forth potential stakeholder (25.81%) registered on the GARUSO platform. Among the registered stakeholders 32 (50.79%) actively participated in the RE process on the GARUSO platform. This means, about half of the registered stakeholders used the RE features to share and evaluate posts and sub-posts. This result is higher compared to previous research results on the active participation of online community members [Nie06].

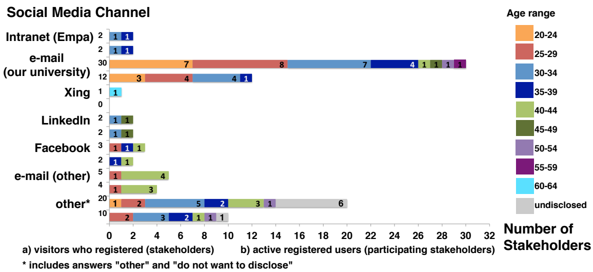
Table 6.8: Summary of the stakeholders' behavior

registered platform visitors (stakeholders)			**63 (100%)**[1]
	who completed their registration		58 (92.06%)
		and actively participated	32 (50.79%)

[1] 25.82% of all potential stakeholders (n=244)

Discussion: Recent research results on online community members who do not actively participate in community discussions show that the average percentage of these so-called lurkers is 90% [Nie06]. The results differ, however, between online communities and communication channels. For example, a study on e-mail based discussion lists shows differences between health-related topics and topics on software support with an average of 46% lurkers and 82% lurkers respectively [NP00]. More recent results in the context of web-based knowledge transfer show even higher shares of lurkers. For example, 89% registered users of Taskcn.com, one of the largest Witkey website in China, are lurkers [YAA08]. Witkey is a web-based system that enables its users to share and buy services and information. Furthermore, 99.99% of all Wikipedia visitors are lurkers [FB11]. Similarly, the results of our study vary between the different online channels. Figure 6.12a shows the numbers of all registered stakeholders (upper bars) and the ones of the active stakeholders (lower bars) per channel. The results reveal that Xing, the e-mail distribution, and 'other' had the highest percentage of lurkers with 100%, 60%, and 50% respectively. Yet, these results need to be considered with caution as it is unclear which online channels were used by the stakeholders who selected 'other'.

KF_SC 2: The stakeholders form a knowledgeable heterogeneous crowd of participants. The results show that the actively participating stakeholders were identified on at least five online channels and had an age range from 20 to 54 (see Figure 6.12a).



(a) Number of stakeholders who registered (upper bar) and actively participated (lower bar) per identification channel and age range.

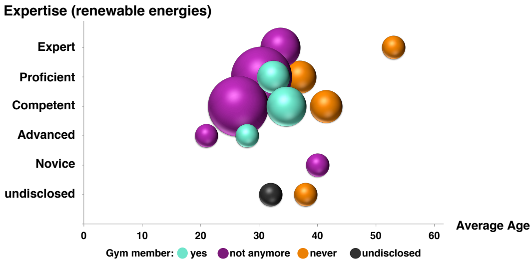
Figure 6.12: Stakeholder analysis.

Their average age was 34.2 and 31.2 years for the male and for the female stakeholders respectively, who all together lived most of their lives in at least nine countries (see Table 6.9). Furthermore, their domain knowledge is rather good: together, they have a considerable level of expertise on renewable energies and experience with going to the gym (see Figure 6.12b).

Table 6.9: Overview of the active stakeholders

gender (average age)	female	19 (31.2)
	male	13 (34.2)
numbers of countries (and users) per continent in which the users have lived most of their lives[3]	Europe[1]	6 (27)
	Asia[2]	1 (2)
	North America[3]	1 (1)
	South America[4]	1 (1)
	undisclosed	1 (1)

[1]CH:13; DE:7; IT:4; AL:1; CS:1; RO:1; [2]IR: 2; [3]CA:1; [4]AR:1;



(b) The bubble size and color represent the number of stakeholders and gym membership, respectively.

Discussion: The results indicate that the participating stakeholders formed a highly heterogeneous and knowledgeable crowd. Highly heterogeneous means that they are diverse with respect to various aspects.

In fact, we found that the results of our study are consistent with the ones that define a crowd in the context of crowdsourcing [HSP+15]: age diversity, gender diversity, spacial diversity, expertise diversity, as well as anonymity, largeness, randomness, and suitability.

With respect to age and gender, our results are furthermore confirmed by the ones on the demographics of participants on Mechanical Turk (turkers) [PCI10, Ipe10], and in Web studies [GVSJ04], which found hat the average age of turkers is 36 with a range of 21 and 35 years, and that on average between 65% and 77% of online participants are female respectively.

In terms of expertise, the accuracy of our results is supported by the way we evaluated the stakeholders' level of expertise.

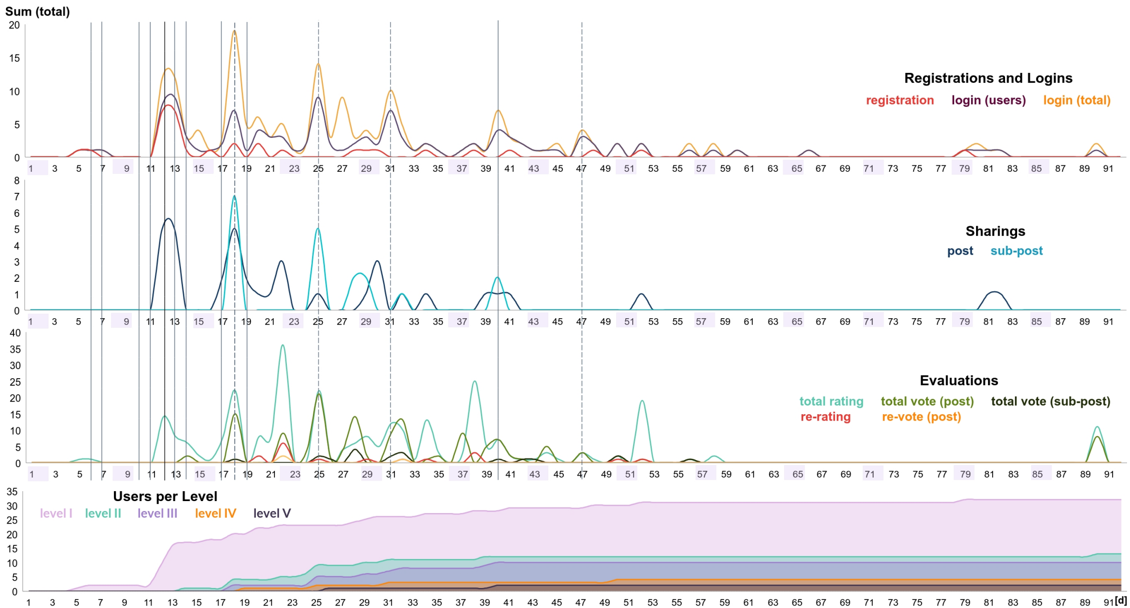
Instead of just asking them during the registration process to select it out of a list, we asked them to complete the sentence *I can name two renewable energies...* with a predefined answer that we mapped as follows to the level of expertise: *Novice:* "No. Not at all."; *Advanced:* "... but am not familiar with any of their benefits and challenges."; *Competent:* "...and am familiar with some of their benefits and challenges."; *Proficient:* "... and explain some of their benefits and challenges."; *Expert:* "... and discuss some of their benefits and challenges with experts." Furthermore, *anonymity* refers to not knowing each other: on the GARUSO platform, the e-mail address, which is required to complete the registration process, is the only information based on which participants are identifiable, yet, it is not revealed to other participants. *Largeness* means in this context that the crowd is large enough to fulfill a task: the number of actively participating stakeholders enable the RE process on the GARUSO platform. *Randomness* of a crowd exists if no criteria were established to select the crowd members: the identification strategy of the GARUSO approach focuses on some initial online channels, yet, the participation on the GARUSO platform is not limited to anyone. *Suitability* describes the capability of a crowd to contribute to the intended purpose. This can, for example, be enabled by giving the crowd members the possibility to voluntarily participate: the participation on the GARUSO platform is voluntarily, the social media based architecture of the platform together with the RE features enable the participants to collaboratively contribute to the RE process, and the gamification engine provides means to motivate them to do so.

Key Findings on Stakeholders Participation (SP)

Subsequently, we present and discuss four key findings on stakeholder participation.

KF_SP 1: The crowd of stakeholders participated on 49 days between day five and 90. Figure 6.13 shows the activities on the GARUSO platform per day. The top graph presents the number of registered stakeholders, logged in stakeholders (*login (users)*) and overall logins, which includes multiple logins of stakeholders (*login (total)*). The two consecutive graphs visualize the RE activities on sharing and evaluating posts and sub-posts. Furthermore, we show the days of the activities that we performed to identify stakeholders and inform the registered stakeholders about the platform activities (see Table 6.6). We use solid lines for stakeholder identification and dotted lines for stakeholder notification. To indicate the weekends, we use a darker background. Together, the three graphs reveal that the stakeholders were active from day five to 90, with increasing periods of inactivity towards the end. The longest period of continuous participation lasts five weeks between day 12 and 46 with only two days (36, 46) of inactivity. The results suggest a relation to our activities on stakeholder identification and notification. Moreover, they provide evidence that the stakeholders were motivated beyond our interactions.

Discussion: The majority of stakeholders registered around day 12 on the GARUSO platform, which is when we started the identification of stakeholders by sending e-mail to students and staff of our university and on the SNSs Facebook, LinkedIn, and Xing.



Solid vertical lines show the activities we took for identifying stakeholders and dotted lines those for notifying stakeholders (see Table 6.6). Weekends are marked with colored bars along the x-axis. *total rating* and *total vote* include *re-rating* respectively *re-vote*. The colors do not have semantics.

Figure 6.13: The stakeholders' activities and their levels of expertise on the Garuso platform per day.

This suggests that the stakeholders registered as a consequence of our activities on stakeholder identification. The results are, however, not as clear for most of the other days. In fact, the stakeholders typically registered several days after our activity on stakeholder identification. In contrast, the results indicate a strong relation between our activities on stakeholder notification and the number of logins. Five of the six days of stakeholder notification show a significant increase in the numbers of logins. Furthermore, the results suggest that the stakeholders were motivated beyond our interactions and independently of the day of the week to participate in the RE process on the GARUSO platform. For example, they indicate that the influence of stakeholder notifications fades over time. In fact, the curve *login (total)* decreases almost linearly from day 18 to 25 and 31 to day 40 and 47, which is similar for the curves on shared sub-post, ratings, and votes on post labels. Moreover, the number of shared posts and in particular of ratings is typically higher on days between interactions than on the ones of interactions. Finally, we did not find any relation between the days of the week and the activities.

KF_SP 2: The gamification engine fosters the stakeholders' motivation to participate. The bottom graph in Figure 6.13 illustrates for each study day the number of stakeholders per expertise level of the GARUSO platform. Together with the two curves on sharing and evaluating above, the results show that on the days where stakeholders reached level II or III the number of activities that are enabled on these levels increased.

This strongly suggests that a core aspect of the gamification engine: the possibility to level up and thereby be rewarded with access to RE features, fosters stakeholder participation on the GARUSO platform.

Discussion. The reward system that we presented in Section 6.5.4 and Table 6.6b defines that the RE features *vote post label* and *share sub-post* are enabled on expertise level II, and *vote sub-post label* on expertise level III. The results in the bottom three graphs of Figure 6.13 show that the number of the corresponding activities increased on most of the days on which stakeholders reached level II or III. For example, stakeholders reached level II on nine days (days 14, 18, 22, 24, 25, 29, 31, 39 and 90). These are also the days on which the curve that illustrates the number of votes on post labels increases, except on day 24. Similarly, the number of shared sub-post is affected. However, with only three overlapping days (18, 25, 29) and one day of delay (40), the assumed effect of reaching level II on the number of shared sub-posts is smaller than the one on the number of votes. This difference reflects, however, the overall results, which show that the number of evaluation activities is higher than the one of shared contributions. With respect to expertise level III, we found further indications that suggest that reaching an expertise level motivates stakeholders to perform activities that are newly introduced on the level. In fact, when stakeholders reached level III (days 18, 25, 29, 31, 32, 39, and 40) the curve of votes on sub-post labels increases, except on the days 29 and 39.

KF_SP 3: Stakeholder participation differs with respect to perceived domain knowledge. Table 6.10 summarizes the results on the stakeholders' participation overall and under consideration of the stakeholders' self-perceived level of domain knowledge (see *KF_SP 2*). To calculate the average values for the logins and views, we used the number of stakeholders per such level. Similarly, we considered the average number of logins for the activities on sharing and evaluating. Overall, the results show that on average the stakeholders logged in 5.53 times on 3.59 days over a period of 13.06 days. During this time, they viewed on average 14.63 times a post, which means that they clicked so many times on posts. Moreover, they shared a total of 10.13 contributions (posts and sub-post) and evaluated 81.01 contributions per average number of logins. With respect to the stakeholders' self-perceived domain knowledge, the results differ. Here, we marked the highest average values blue per activity. Due to the lack of information and only one participant, we did not evaluated the categories Undisclosed and Novice, respectively. This is why they are in Italics.

Discussion: Most stakeholders perceived their domain knowledge competent (12) or proficient (11) and only few considered it expert (4) or advanced (2). One stakeholder, furthermore, indicated to be a novice with respect to the application domain and two did not disclose any information on that matter. The results show that the maximum average values for the three categories: *Login*, *Views*, *RE activities*; appear among the stakeholders with one of the top three levels of domain knowledge.

Table 6.10: Summary on the stakeholders' activities

Self-perceived expertise: renewable energies	**n**[1]	**Logins**					**Views**		**RE Activities**			
		sum		**days**		**Δ days**[2]			**share**		**evaluate**	
		tot.	**avg.✦**	**tot.**	**avg.✦**	**avg.✦**	**tot.**	**avg.✦**	**tot.**	**avg.✭**	**tot.**	**avg.✭**
Expert	4	27	6.75	11	2.75	4.25	60	15	13	1.93	48	7.11
Proficient	11	56	5.09	45	4.09	12.27	196	17.82	17	3.34	202	39.67
Competent	12	68	5.67	41	3.42	17.33	126	10.5	17	3	104	18.34
Advanced	2	2	1	2	1	1	3	1.5	2	2	1	1
Novice	*1*	*12*	*12*	*9*	*9*	*20*	*39*	*39*	*1*	*0.08*	*46*	*3.8*
Undisclosed	*2*	*12*	*6*	*7*	*3.5*	*18*	*44*	*22*	*6*	*1*	*47*	*7.83*
Total	**32**	**177**	**5.53**	**115**[4]	**3.59***	**13.06**	**468**	**14.63**	**56**	**10.13**	**448**	**81.01**

[1] number of actively participating stakeholders; [2] days between the first login (registration day) and the last login on the GARUSO platform; ✦ per stakeholder; ✭ per avg. number of logins; [4] person-days * per person-days.

Table 6.11: Overview of the stakeholders' RE activities

Self-perceived expertise: renewable energies	Shared Posts		Shared Sub-Posts		Rated Posts*		Voted Post Labels*		Voted Sub-Post Labels		Re-Ratings		Re-Voted Post Labels		Stakeholders per Expertise Level				
	sum	avg. ❶	sum	avg. ❷	sum	avg. ❶	sum	avg. ❷	sum	avg. ❸	sum	avg. ❶	sum	avg. ❷	I	II	III	IV	V
Expert	6	1.5	7	7✖	36	9	10	10	2	2	1	1			3				1
Proficient	12	1.09	5	1	125	11.36	68	13.6	9	2.25	8	2.67			6	1	3		1
Competent	11	0.92	6	1.5	68	5.67	31	7.75	5	1.67	2	1			8	1	1	2	
Advanced	2	1	✗	✗	1	0.5	✗	✗	✗	✗			✗	✗	2				
Novice	*1*	*1*			*30*	*30*	*16*	*16*	✗	✗	*4*	*4*	*2*	*2*		*1*			
Undisclosed	*5*	*2.5*	*1*	*0.5*	*28*	*14*	*16*	*8*	*3*	*1.5*	*2*	*1*	*1*	*0.5*				*2*	
Total	**37**	**1.16**	**19**	**1.46**	**288**	**9**	**141**	**10.85**	**19**	**1.9**	**17**	**1.89**	**3**	**0.23**	**19**	**3**	**6**	**2**	**2**

* including re-ratings respectively re-votes; ✗ feature is not enabled; ★ number of shared post and sub-posts; ✦ number of evaluations (ratings and votes);
❶ elicitation features enabled on expertise level I; ❷ elicitation feature enabled on expertise level II; ❸ elicitation feature enabled on expertise level III. ✖ due to one participant in this category who could have performed this activity, we did not consider this average value.

In terms of logins, on average the self-perceived experts logged in most times (6.75), the proficient ones on most days (4.09), and the advanced ones over the longest period of time (17.33). Thereby, it is striking that in this group the experts logged in most times, yet, by far over the shortest period of time (4.25).In contrast, the stakeholders with proficient domain knowledge logged in the fewest times (5.09) but distributed over most days (4.09). With respect to the number of views and RE activities, the stakeholders who considered their domain knowledge proficient were most active on average. In fact, they have the highest average number of post views (17.82) and of RE activities for both sharing (3.34) and evaluating (38.67).

KF_SP 4: The Stakeholders' RE activities focused on requirements prioritization. Table 6.11 shows the results on the RE activities on the GARUSO platform. The circled numbers in the second row show the expertise level on which the corresponding activity is enabled. To calculate the average values, we used the number of stakeholders per expertise level, as presented to the right of the table. Like before, the highest average values are marked blue. As in Table 6.10 above, we did not consider the values in Italics. Furthermore, we did not we did not consider the average value of shared sub-posts for the expert category due to only one participant in this category who was on an expertise level where this activity could have been performed. The stakeholders performed 504 RE activities on the GARUSO platform. Thereby, they focused on evaluation activities throughout all expertise levels. Overall, the stakeholders shared 56 (11.11%) contributions and evaluated 448 (88.89%).

With respect to the activities enabled on expertise level I, they shared 37 posts and rated 88. With focus on the activities introduced on expertise level II, they shared 19 sub-posts and voted on 141. Moreover, they voted 19 times on sub-posts, which was possible on expertise level III and above.

Discussion: In online social media based RE processes, activities that support the prioritization of requirements such as rating and voting typically require less effort than activities for sharing content. Thus, it seems obvious that the former are performed more often than the latter on a social media platform such as GARUSO. However, previous research results do not necessarily confirm this assumption.

For example, a study on the potential of Facebook to support the elicitation and prioritization of requirements [STC+15] shows a preference among the study participants to share posts. In fact, the evaluation of posts made only 32.77% if the participants were not explicitly asked to evaluate, and 53.01% if they were explicitly asked to do so. In contrast, the results of our study show a rather clear tendency towards evaluation activities. Thereby, the results of our study are consistent with the ones of a previous study on participatory RE on the online elicitation platform REfine [SDB+15].

Overall, the results of the three studies suggest that activities on requirements prioritization are more numerous compared to the ones on requirements elicitation if the activities are performed on social media platforms that have an explicit RE purpose.

However, the study results can only partially be compared with each other. For example, neither of the two studies that were not conducted by us focused on stakeholders outside organizational reach. Furthermore, with two and four weeks respectively they were shorter than our study. Moreover, the gamification concept of REfine follows a different strategy which focuses on competition whereas the one of the GARUSO platform addresses several aspects of motivation and considers the stakeholders' changing experience over time. Despite these differences, we think that together the results of the three studies provide valuable insights for the future design of RE platforms.

Key Findings from Stakeholder Feedback

The GARUSO platform includes a feedback form, which is accessibly on the navigation bar (see Figure 6.7) to all registered stakeholders. Furthermore, the stakeholders are automatically directed to it when they reach expertise level III and V. The feedback is voluntary and free of any rewards or incentives. The feedback form includes questions and comment fields. To be able to most accurately derive the stakeholders' attitudes, we use semantic differential scales [OST64] with an even number of scale points for questions on familiar topics [CI80]. 13 stakeholders gave feedback. Three of them were on expertise level I, one on level II, and nine on level III.

In Figures 6.14 and 6.15 we show the results. We used spider diagrams in which the concentric threads represent the scale points.

The further away they are from the center, the more positive the answers. To visually separate the negative answers from the positive ones we added a circle. Furthermore, we used letters for their self-perceived domain knowledge: E,P,A,and ? for Experts, Proficient, Advanced, and undisclosed, respectively.

KF_SF 1: The GARUSO platform is easy to understand and interesting to use. Figures 6.14 illustrates how the stakeholders perceive the GARUSO platform overall. The results show that the three evaluation criteria *usability*, *impression*, and *experience* were positively rated by the majority of the stakeholders. Furthermore, the majority perceived the GARUSO platform easy to use and had a good or very good impression about it. Moreover, they experienced their participation on the GARUSO platform as interesting or even very interesting. Only one stakeholder (ID 41) perceived using the GARUSO platform as hard and preferred not to disclose an opinion on the overall impression, yet, experienced the participation on the platform as good.

KF_SF 2: The rewards have different motivational effects on the stakeholders. Figure 6.15a shows how motivating the different rewards of the gamification engine were perceived by the stakeholders. We set the scale value for challenges and badges on *undisclosed* for the stakeholders on level I as they had no access to them. The results show that the stakeholders felt motivated by the rewards overall, yet, with different intensity. The most effective rewards in terms of motivation were earned points and access to upper levels followed by access to information, which enables normative comparisons.

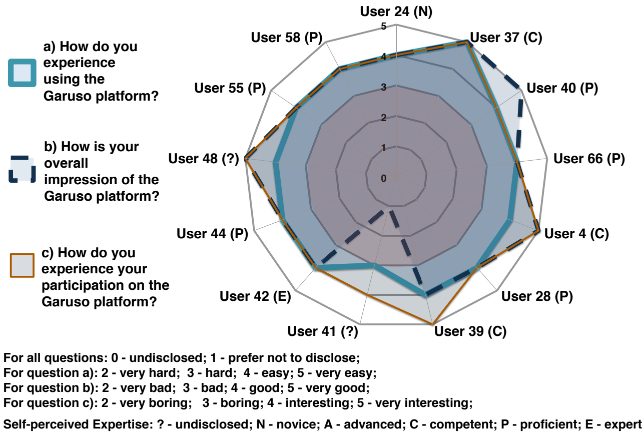
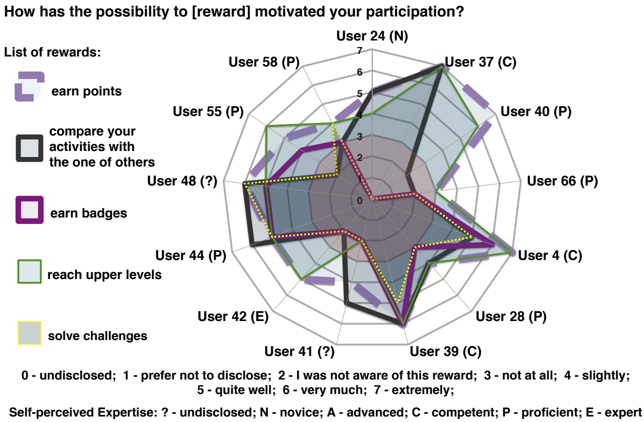


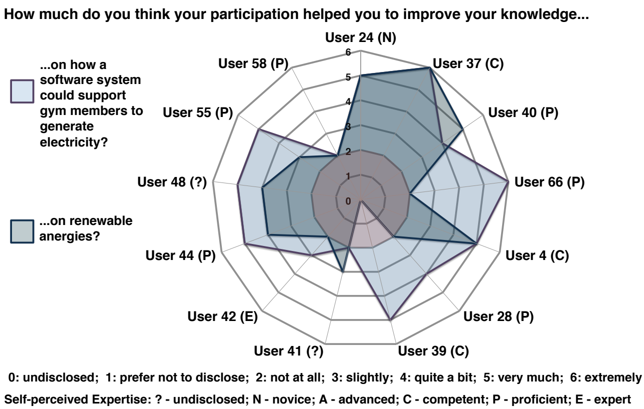
Figure 6.14: Overall impression on the Garuso platform.

However, they were also controversial with each at least one stakeholder who perceived them extremely motivating and one who perceived them not motivating at all. In contrast, the perception about the motivational power of solving optional challenges and earning badges was more balanced between stakeholders. However, compared to the other rewards it was lower overall. Furthermore, one stakeholder did not perceive any of the rewards motivating (ID 66) and five were unaware of some of the rewards (ID 40-42,55,66).

KF_SF 3: The motivation concept supports stakeholder development during the RE process. Figure 6.15b shows the stakeholders' feedback on the development of their knowledge on 1) how a software system could be beneficial in the application domain, and 2) the application domain of renewable energies itself.



(a) Overall impression on the Garuso platform.



(b) The platform users' development.

Figure 6.15: Feedback on the effectiveness of the gamification engine.

The majority of the stakeholders stated that their participation on the GARUSO platform improved their knowledge on both subjects very much or even extremely. Two stakeholders did not perceive any improvement of their knowledge on the potential of a software system in the application domain. Furthermore, four did not improve their knowledge on renewable energies, yet, all of them initially perceived their domain knowledge proficient or expert.

6.6.4 Lessons Learned

Figure 6.12 summarizes the key findings of our evaluation of the GARUSO approach. The empirical nature of our study makes it impossible to statistically test the results of our evaluation. We were, however, able to derive 14 first design principles (DPs) from the key findings that we presented above. The DPs provide guidance for how to identify stakeholders outside organizational reach and motivate them to participate in RE activities on social media based platforms. Thereby, we consider them to contribute to the field of crowd RE beyond the GARUSO approach.

Next, we present the DPs with respect to stakeholder identification and participation. For each of DPs, we described how we derived them from our key findings and summarized them in Table 6.13.

Stakeholder Identification

To create an effective identification strategy for stakeholders outside organizational reach, we suggest four design principles (DP 1 - DP 4).

With **DP 1** we consider that the identification of stakeholders outside organizational reach is most effective for online channels which by their nature address existing communities. This is, for example, the case with SNS groups or mailing lists (KF_SI 1-4).

DP 2 refers to the fact that the use of diverse online channels increases the heterogeneity of the crowd of participating stakeholders (KF_SI 4).

The use of diverse online channels requires, however, more resources than the focus on few channels. This is because these channels need to be evaluated to understand their users, which is for example needed to create online advertisements. **DP 3**, therefore, suggests to only consider a few, yet, popular online channels if the focus is on the number of identified stakeholders rather than on their heterogeneity, or if resources are scarce (KF_SI 3).

Furthermore, **DP 4** considers the circumstance that the frequent application of the identification strategy during the entire RE process supports the effectiveness of the RE process over time (KF_SI 1).

Table 6.12: Overview of the key findings

Key Findings on Stakeholder Identification	
KF_SI 1:	Every third visitor is a potential stakeholder.
KF_SI 2:	The visitors accessed across all continents with regional differences.
KF_SI 3:	The largest sources of access are not the most effective ones with respect to potential stakeholders.
KF_SI 4:	The variety of online channels enhanced the RE process.
Key Findings on Stakeholder Characteristics	
KF_SC 1:	Overall, stakeholder participation is above average.
KF_SC 2:	The stakeholders form a knowledgeable heterogeneous crowd of participants.
Key Findings on Stakeholder Participation	
KF_SP 1:	The crowd of stakeholders participated on 49 days between day five and 90.
KF_SP 2:	The gamification engine fosters the stakeholders' motivation to participate.
KF_SP 3:	Stakeholder participation differs with respect to perceived domain knowledge.
KF_SP 4:	The Stakeholders' RE activities focused on evaluation.
Key Findings from Stakeholder Feedback	
KF_SF 1:	The GARUSO platform is easy to understand and interesting to use.
KF_SF 2:	The rewards have different motivational effects on the stakeholders.
KF_SF 3:	The motivation concept supports stakeholder development during the RE process.

Table 6.13: Overview of proposed design principles

#	Design Principle for Stakeholder Identification	Influenced by KF
1	Focus on online channels, which by their nature address existing communities.	SI 1-4
2	Use diverse online channels to increase the heterogeneity of the stakeholder crowd.	SI 4
3	Use popular online channels to increase the crowd size or if you cannot afford high effort.	SI 3
4	Run the identification strategy several times during the RE process.	SI 1
#	**Design Principle for the RE Platform**	**Influenced by KF**
5	Create a strong registration process.	SC 1-2; SP 1
6	Implement a newsletter service that regularly informs the stakeholders on the RE process.	SI 1
7	Apply levels of expertise that gradually introduce RE features as reward for participation.	SP 2; SF 2-3
8	Apply different game elements that consider the player types and are not mandatory to level up.	SP 3; SF 2
9	Use points reasonably.	SF 1
10	Apply a content structure where posts present simplified user stories and sup-post extend them.	SF 1; SP 4
11	Provide different means to introduce the RE platform to the stakeholders.	SC 1
12	Consider the stakeholders' domain knowledge in the rules that define the criteria to reach upper levels.	SC 1
13	Consider the possibility to performed RE activities in the rules that define the criteria to reach upper levels.	SP 4
14	Provide a visual summary of all new features and rule when entering a new expertise level.	SF 2

Stakeholder Participation

To effectively facilitate the collaborative participation of stakeholders outside organizational reach in RE activities, we suggest ten DPs (DP 5 - DP 14).

The stakeholders continuously participated over an extensive time span in the RE process on the GARUSO platform (KF_SP 1). This indicates a successful identification strategy. Furthermore, we assume that the registration process repelled potential malicious users, which positively affects the participation. With **DP 5** we, therefore, suggest a strong registration process.

DP 6 considers that the stakeholders were motivated by the notification messages that we sent to inform them about the state of the RE process (KF_SI 1).

Moreover, evidence strongly suggests that our gamification approach successfully motivated the stakeholders to collaboratively participate in the RE activities over time. With **DP 7** we consider the indicated relation between the expertise levels and the platform activities (KF_SP 2 and KF_SF 2), as well as the one between the expertise levels and the stakeholders' increased domain knowledge (KF_SF 3).

Based on their feedback, the stakeholders had different perceptions on how motivating the single game elements were (KF_SF 2). Furthermore, they were highly heterogeneous (KF_SC 2, KF_SP 3). Overall, these results indicate that the stakeholders' heterogeneity is successfully considered by the motivation concept of the GARUSO platform.

With **DP 8** we, therefore, suggest the use of game elements which respect different player types to improve individual playful experiences, and which are not mandatory to level up.

In terms of usability, the majority of participating stakeholders who provided feedback stated that the platform was easy to use (KF_SF 1). We assume that the reasonable application of points supports the usability of the platform, which we address with **DP 9**.

Furthermore, with **DP 10** we consider the adapted structure of user stories to successfully support the usability of the GARUSO platform. On one side it is simple to understand (KF_SF 1). On the other side, it reflects the collaborative nature of the platform (KF_SP 4).

Some stakeholders did not actively participate in the RE activities on the GARUSO platform after their registration (KF_SC 1). One reason for their passivity might be the onboarding process. Onboarding is, however, required to ensure equal knowledge about the RE platform among the participating stakeholders. Yet, we think if the stakeholders can choose how to learn about the platform features they are more likely to finish the onboarding process, which we express with **DP 11**.

Similarly, some stakeholders with a high self-perceived domain knowledge stopped their participation while they were on the first two levels (KF_SP 4). We assume that one reason for their dropout is the restricted access to RE features on these levels.

In fact, the limited access hinders these stakeholders to fully apply their knowledge. However, knowing the application domain is different from understanding the platform features and the participating community. We therefore suggest with **DP 12** to keep the concept of expertise levels for all participating stakeholders but, to consider the domain knowledge in the rules that define the criteria to level up.

The participating stakeholders focused on evaluation activities (KF_SP 4). However, these activities depend on the availability of shared posts and sub-posts. In fact, the number of shared posts sets the limit for the number of ratings that a stakeholder can perform. We address this aspect with **DP 13**, which proposes to also consider the possibility to perform an RE activity in the criteria that need to be fulfilled to level up.

Finally, to ensure that the stakeholders are aware of all opportunities provided per expertise level, **DP 14** suggests to visualize all the features that are newly introduced on a level at the moment when accessing a level for the first time.

6.6.5 Threats to Validity

In this section, we discuss relevant threats to the validity of our study according to the categorization by Wohlin et al. [WRH+12]. With respect to stakeholder identification we perceive the same threats as discussed in Sect. 6.4.8. This is why we focus on stakeholder participation.

Internal Validity: The empirical nature of our study limits its internal validity as it inhibits the control of potentially confounding factors. A possible threat is that the majority of stakeholders who participated in the RE activities on the GARUSO platform were identified through a single channel (the e-mail distribution). However, we do not consider this a major threat of selection as participation was anonymous and voluntary and the overall crowd was highly heterogeneous. Yet, since participation was voluntarily, the results on the effectiveness of the Gamification Engine to motivate stakeholders could be biased due to the intrinsic motivation of the participating stakeholders. Intrinsic motivation is, however, a prerequisite of gamificiation. Therefore, we do not consider this a major threat. Furthermore, we believe to have addressed the threat of history as the study lasted for three months.

External Validity: The effects caused by game elements (and by the algorithms controlling them) depend on the context in which gamification is applied. Therefore, the results of our study cannot just be generalized to other fields. We think, however, generalization is possible in the context of crowd RE. In particular, the participation was anonymous and voluntary and we did neither coerce the participants nor motivate them other than with the rewards of the Gamificiation Engine to participate in the RE activities on the GARUSO platform. Furthermore, we cannot exclude that some participants might not have been stakeholders, but contributed to the study in order to support our research. This threat is partially addressed by the design of the registration process.

Furthermore, due to the extensive duration of the study we do not consider this a serious threat as it is rather probable that potential *non-stakeholders* dropped out at early stages.

Construct Validity: One potential threat is the absence of a ground truth against which we could evaluate the results of our study. To address this threat we used the results of the monitored activities on the GARUSO platform and the ones of the participants' feedback for the subsequent analysis and compared them where possible with study results of related research fields. Therefore, we do not consider mono-method bias a major threat. However, to completely mitigate this threat, the results need to be compared with the ones of further studies conducted with the GARUSO approach. To address possible evaluation stress we assured all stakeholders that their data were treated confidentially and evaluated for research purposes only. Furthermore, the GARUSO platform provides multi-language support to address potential language barriers. Another possible threat is given by social niceties, which have might have biased the stakeholders' feedback. However, the stakeholders did neither gain anything for giving positive feedback nor loose anything for a negative one. Therefore, we do not consider this aspect a major threat. Similarly, malicious stakeholders who would have wanted to cheat the system might have influenced the number and values of ratings and vote. This could potentially have slowed down the other stakeholders to level up and eventually demotivated them. We addressed this threat with the registration process. Furthermore, it is limited by the number of participating stakeholders.

However, the possibility to directly report suspicious activities from the GARUSO platform and algorithms that check for according patterns would furthermore reduce this threat.

Conclusion Validity: We addressed measure reliability with the onboarding process that ensures equal knowledge of the stakeholders with respect to the basic features of the GARUSO platform. Subsequently, the advanced RE features are enabled per expertise level. In addition, the GARUSO platform provides an FAQ page and a contact form. The motivation concept and the rules that define the criteria of reaching a level are derived from existing work [HKG17a, HKG17b]. We limited the risk of wrongful evaluations by allowing the stakeholders to change their ratings and votes at any time, and randomized the order of shown posts to prevent that new posts are always shown first. Furthermore, we evaluated a large number of data points. We monitored every activity on the GARUO platform over 92 days and asked the stakeholders about their subjective feedback on different aspect of the GARUSO platform. The evaluation of both data sets shows consistent results. Moreover, the stakeholders could participate at any time and from anywhere. In particular, the responsive design of the GUI that considers the screen size of the accessing device enabled them to participate on the GARUSO platform with desktop and mobile devices alike. In terms of random heterogeneity of the participants, this is actually what we wanted. In fact, the goal of our study was to evaluate the GARUSO platform with respect to stakeholders outside organizational reach, who due to their nature most likely build a highly heterogeneous crowd of stakeholders.

6.7 Related Work

Researchers in different fields started to tap into the potential of crowds of online communities to solve tasks. This development increases the need for strategies to identify or attract potential users, participants, and stakeholders. For example, in the context of crowd sourcing, users are, typically, attracted with monetary incentives as for example on Amazon Mechanical Turk [Tur]. Yet, monetary incentives are assumed to bias the participants, which is why researchers started to look for alternatives such as the use of advertisements networks [IG14]. Furthermore, the process of sowballing was previously applied in RE to support the continuous recommendation of stakeholders by already identified ones [LF12].

Moreover, recent RE approaches emphasizes the benefit of online collaboration between stakeholders. In fact, researchers increasingly focus on social interactions that collaboratively involve stakeholders to support the prioritization of requirements [TCBB09]. For example, WikiWinWin [YWK+08] provides the possibility to collaboratively brainstorm needs and rate them with respect to different predefined criteria such as business importance and ease of realization. More recently, an approach from the domain of Social RE [LDHH09] used a web platform that enables stakeholders to rate shared needs on a scale and to vote for or against them. Furthermore, with respect to massive user involvement, Liquid RE [JM15] suggests to empower stakeholders to delegate their vote to others.

In this evolving Web-based and collaborative RE context researchers have recently highlighted the importance of the stakeholders' motivation and as a consequence started to investigate the potential of gamification. For example, iThink [FDR+12] is a web-based gamification environment and REfine [SDB+15] an RE platform that applies gamification. Both approaches yielded satisfying results in terms of numbers and quality of generated requirements. Furthermore, recent results by Lombriser et al. [LDLB16] show that if stakeholders are motivated with game elements to elicit requirements on a digital platform they support the elicitation process more effectively. The efforts to investigate how to apply gamification in RE, furthermore, evolves towards the engagement of crowds of stakeholders, as recently shown by Dalpiaz et al. [DSB+17]. All these approaches have, however, focused on stakeholders *within* organizational reach.

Kolpondinos and Glinz [HKG17b] have contributed a stakeholder motivation concept for gamification approaches in RE which works in the context of stakeholders outside organizational reach. They also have investigated the influence of gamification algorithms on the collaborative prioritization of requirements [HKG17a]. We use both results for the construction of the gamification engine of the GARUSO platform.

6.8 Conclusions and Future Work

We have presented GARUSO, an approach for involving stakeholders outside organizational reach in the collaborative elicitation and prioritization of requirements. GARUSO uses gamification for attracting stakeholders and motivating them to contribute.

To evaluate our approach, we performed a field trial over a period of three months, which demonstrates that the GARUSO approach works and is effective. We attracted visitors from all over the world to the GARUSO platform, resulting in the identification of a crowd of stakeholders outside organizational reach. Our evaluation also revealed that gamification can be applied effectively for motivating the identified stakeholders to participate in collaborative online RE processes. Further, our results highlight the importance of a customized motivation concept as a foundation for the gamification approach. Finally, we have derived a first set of design principles from our results, which may serve as guidance for how to identify and motivate stakeholders in the context of crowd RE with focus on stakeholders outside organizational reach.

Future work is needed to assess the efficiency of the RE processes enabled by GARUSO, the quality of the resulting requirements, and the limitations of the approach. We plan to study these issues and also encourage other researchers to try and further evolve the GARUSO approach.

Chapter 7
Conclusions

7.1 Thesis Summary and Achievements

The success of software systems depends to a large extent on the effectiveness of RE approaches to identify stakeholders and to enable and motivate them to participate in RE activities. This effectiveness is essentially challenged with respect to ubiquitously deployed and openly available software systems. The stakeholders of these software systems are typically outside organizational reach. This means, they are not members of the organizations which commission or build the system nor of any well-known related organization. So far, RE approaches were not designed for these stakeholders. We were interested in how stakeholders can be identified and motivated beyond organizational limits to participate collaboratively in RE activities. For this purpose, this dissertation explores the potential of social media and gamification.

The cornerstones of this dissertation are highlighted in the following by revisiting the research questions that are presented in Section 1.5.

RQ1: How can gamification facilitate collaboration on online platforms and how can indirect effects of software systems be considered during requirements elicitation?

We answered this research question with two sub-questions on gamification and indirect effects each, and elaborated on these sub-questions in Chapter 2 and Chapter 3, respectively.

RQ1.1: How can gamification be applied to an online platform so that the platform users get motivated to participate collaboratively on the platform with respect to the intended purpose of the platform?

Chapter 2 presented main limitations of persuasive technologies with respect to motivating users of social media platforms towards collaborative activities on these platforms. It also showed how we address these limitations with gamification. The results of the literature overview that we performed in the fields of psychology, persuasive technology, eco-feedback technology and game design, and their consecutive assessment uncovered key design requirements of such a gamification approach. We found that the approach should consider the users' individuality, respect their autonomy and support social interactions. In addition, the platform users should be enabled to acquire new skills and to improve their competence level. They also should be authorized to decide which activities to take to do so and have access to normative comparisons.

RQ1.2: How can indirect effects of software systems be considered during the elicitation of requirements for these systems?

Chapter 3 showed the results of an exploratory case study that we conducted in domestic canteens of a global catering company. In the study we investigated how indirect effects of a software system can be addressed during the elicitation process. We used a mixed methods approach [ESSD08] in which we consecutively applied three elicitation techniques. Firstly, we performed two contextual inquiries. Based on the observations made during the inquiries we designed interview questions and subsequently conducted 19 semi-structured interviews with meal planners from different canteens. Finally, we created an online questionnaire to explore the interview results further. The questionnaire was posted in the shared intranet of the canteens and completed by 60 meal planners across canteens. The overall findings suggest that enabling stakeholders to label their wishes and needs with respect to (potential) indirect effects during the elicitation process helps RE experts to address these effects. The findings also indicate that (potential) indirect effects of a software system can be addressed with both traditional functional and non-functional requirements. Moreover, the findings provide evidence that involving so-called indirect stakeholders, i.e., stakeholders who do not utilize a software system but are affected by its utilization (which makes them likely to be outside organizational reach) in RE activities supports the identification of (potential) indirect effects of the system.

RQ2: What is an effective design of gamification so that it motivates stakeholders outside organizational reach to participate collaboratively in activities on a social media platform which supports the elicitation and prioritization of requirements?

Chapter 4 presented an early version of the Motivation Concept, which builds the foundation of its later version applied to the GARUSO Platform. This chapter showed how the concept design considers the key requirements for gamification that we derived from the research described in Chapter 2. It also presented how the concept design is inspired by theories from motivational psychology, learning psychology and economy, as well as from best practices in game design. As a result, the Motivation Concept provides a means to address the high heterogeneity of stakeholders outside organizational reach over time while keeping the focus on RE purposes. Hence, it provides the foundation of the gamification approach applied on the GARUSO Platform.

RQ3: What effects do gamification algorithms of a social media platform for requirements elicitation and prioritization have on the platform activities of stakeholders outside organizational reach?

Chapter 5 reported on a field experiment that was conducted with two independent groups of stakeholders to evaluated the effects of gamification algorithms, i.e., algorithms that control game elements. All participants of the field experiment were stakeholders outside organizational reach.

On an early version of the GARUSO Platform we investigated two different motivation strategies. The two strategies were applied in both groups but implemented with different gamification algorithms per group. The results of the experiment reveal statistically significant differences between the influence of these gamification algorithms on the stakeholders' platform activities. The results also suggest a pattern to effectively motivate stakeholders outside organizational reach to participate over time in RE activities on social media platforms. This pattern indicates that the stakeholders are most motivated to participate if the difficulty to reach goals increases at the beginning decreases afterwards and increases again after a while. We used these findings to improve the effectiveness of the Motivation Concept that was previously presented in Chapter 4.

RQ4: To what extent does our approach motivate stakeholders outside organizational reach to collaboratively participate in activities on social media platforms that support the elicitation and prioritization of requirements?

Chapter 6 presented the overall GARUSO approach with the GARUSO Platform and the Identification Strategy, and reported on its evaluation. The GARUSO Platform is a prototype that facilitates the collaborative participation of stakeholders in RE activities. What makes the GARUSO Platform special is that it works beyond organizational limits. It can also be used in distributed settings and scales well. The features of the RE Engine support the collaborative elicitation and prioritization of requirements and the applied gamification approach motivates stakeholders outside organizational reach to participate in these RE activities. We developed the GARUSO Platform together with the Motivation Concept as well as the Identification Strategy each in an iterative process based on the findings derived from the previous research questions. The Motivation Concept effectively motivates the stakeholders to participate on the platform over time. The Identification Strategy attracts (potential) stakeholders to the GARUSO Platform. It suggests the creation of personas, which base on player types, and the design of online advertisements for these personas. It also proposes the selection of diverse online channels such as social network sites and e-mail services to distribute the advertisements.

To evaluate the GARUSO approach we investigated the attracted (potential) stakeholders, their platform interactions and their voluntary feedback.

Firstly, Google Analytics was used to analyze the platform visits. The results show that the GARUSO Platform was accessed by visitors from around the world. Most of them accessed through one of the online channels that were initially used to distribute the online advertisements. Secondly, the data of the users' profile, which needed to be completed during the registration process on the GARUSO Platform was stored. Its analysis showed that the identified stakeholders were highly heterogeneous. Thirdly, all platform activities were monitored with algorithms. The results of the subsequent analysis strongly indicate that the gamification approach applied on the GARUSO Platform is successful. For example, the number of active platform users was above average compared to results of similar studies in other fields. The platform users also voluntarily participated continuously over five consecutive weeks, except for two days. Finally, the data of the questionnaire, which was integrated in the GARUSO Platform and optional to complete, provides evidence that the GARUSO Platform is easy to understand and interesting to use. The data also suggests that the Motivation Concept increases the stakeholders' knowledge about the application domain of a software system for which the requirements are elicited and prioritized.

The answers to the research questions verify the thesis statement. This shows that gamification can be applied to social media platforms that support RE activities so that stakeholders outside organizational reach participate voluntarily and collaboratively in these platform activities.

In conclusion, we consider our approach to successfully facilitate stakeholder participation beyond organizational limits.

7.2 Outlook

The GARUSO approach is - to the best of our knowledge - the first RE approach that considers stakeholders outside organizational reach. The GARUSO Platform, however, is still a prototype. This gives room for further improvements and evaluations.

With the focus of our research on participation, the current prototype of the GARUSO Platform does not reward users for identifying stakeholders. To increase the effectiveness of the snowballing process, a future implementation should consider stakeholder identification in the Motivation Concept. Such an approach is likely to positively affect the participation of stakeholders. In fact, the evaluation of the GARUSO approach suggests quite strongly that continuous stakeholder identification leads to more continuous participation on the platform.

A further way to improve the GARUSO approach is to apply rules that are flexible with respect to specific criteria. The current version uses static thresholds for the rules applied by the gamification algorithms. These thresholds derived from the results of our previous research. However, as they are static they can temporarily limit the platform users' potential to perform activities. For example, if a user needs more evaluation points to level up but has already evaluated all available (sub-) posts leveling up is not possible until another user shares a (sub-) post. This issue can be addressed with gamification algorithms that consider the users' individual potential to perform an activity.

To improve such an approach, the algorithms should also consider the activities a user has performed from the moment a rule was triggered for this user. This will eliminate situations in which a user is rewarded without having performed all activities required by a rule if these activities cannot be performed right away.

In accordance with the research scope, the current prototype has no automatic notification mechanism to inform the platform users with periodic summaries of platform activities. Instead, we simulated such a mechanism with manually generated notifications. The final evaluation gives strong evidence that notifications bring the stakeholders back to the platform. Therefore, a future implementation should include an automated notification mechanism.

Another way to improve the GARUSO Platform is to explicitly inform the stakeholders about game elements that are offered on their current expertise level of the platform. In fact, the final evaluation of the GARUSO approach reveals that some platform users where unaware of single available game elements. One way to address this issue is to present an overview of all enabled game elements the moment a stakeholder reaches a new level. However, a solution as such is not in favor of the explorer player type who prefers to discover a system on own terms. A solution that displays explicit information about new game elements on demand could solve this challenge. In addition, this solution should detect game elements that are not used according to predefined criteria, which could be set to ensure equal knowledge about the available platform features among all users. Such a solutions would make it possible to push the information on “unperformed” activities while minimizing the risk to upset the explorer player types.

Finally, the results of the evaluation depend on the participation of the stakeholders. However, the number and heterogeneity of participating stakeholders is not influenced by the GARUSO approach alone but also by external factors which are out of its control. For example, political discussions on privacy concerns are very likely to influence people's perception of software systems that monitor their activities. Further studies are needed to investigate the impact of such factors on the effectiveness of the GARUSO approach.

The scientific foundation of the GARUSO approach and the results of its evaluation provide evidence that strongly indicates that the GARUSO approach also supports the quality of the elicited and prioritized requirements. To investigate this aspect future evaluations need to focus on quality criteria. Such a qualitative evaluation can be supported with content analysis and machine learning techniques in a similar way as done for the analysis of tweets [GAS16].

In summary, the evaluation results show that the GARUSO approach facilitates stakeholder participation beyond organizational limits in RE. Evidence also suggests that the GARUSO approach lays groundwork for future solutions and research directions in CrowdRE with focus on the stakeholders' heterogeneity. We also see the GARUSO approach as a contribution to the field of RE4SuSy with focus on (potential) indirect effects of software systems. Finally, we consider the GARUSO approach to inspire software solutions that value both their users' experience and their playfulness.

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Appendix A

Publications

This appendix presents the list of publications on which this cumulative dissertation is built.

A.1 Journal Articles

[HKG18] Martina Z Kolpondinos and Martin Glinz. GARUSO: A Gamification Approach for Involving Stakeholders Outside Organizational Reach in Requirements Engineering. Working Paper. Under review at the *Requirements Engineering Journal (REJ)*, 2018.

A.2 Book Chapters

[HH15] Martina Z. Huber and Lorenz M. Hilty. Gamification and sustainable consumption: Overcoming the limitations of persuasive technologies. In collection *ICT Innovations for Sustainability*, 2015.

A.3 Conference Papers

[HKG17a] Martina Z Huber Kolpondinos and Martin Glinz. Behind Points and Levels - The Influence of Gamification Algorithms on Requirements Prioritization. In *25th International Requirements Engineering Conference (RE)*, 2017.

A.4 Workshop Papers

[HHG15] Martina Z Huber, Lorenz M Hilty, Martin Glinz. Uncovering Sustainability Requirements: An Exploratory Case Study in Canteens. In *5th International Workshop on Requirements Engineering for Sustainable Systems (RE4SuSy)@RE*, 2015.

[HKG17b] Martina Z Huber Kolpondinos and Martin Glinz. Tailoring Gamification to Requirements Elicitation: A Stakeholder Centric Motivation Concept. In *10th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE)@ICSE*, 2017.

A.5 Further Publications (not included in the Thesis)

[MSHO+15] Brigitte Maranghino-Singer, Martina Z Huber, David Oertle, Marc Chesney, Lorenz M. Hilty. An Information System Supporting Cap and Trade in Organizations. In collection *ICT Innovations for Sustainability*, 2015.

[SSF+17] Norbert Seyff, Melanie JC. Stade, Farnaz Fotrousi, Martin Glinz, Emitzá Guzmán, Martina Z Kolpondinos-Huber, Denisse Muñante, Marc Oriol, Ronnie Schaniel. End-user Driven Feedback Prioritization. In *1st International Workshop on Requirements Prioritization and Enactment (PrioRE)@REFSQ*, 2017.

Curriculum Vitae

Name:	Martina Kolpondinos (born Huber)
Date of Birth:	October 29, 1977
Citizenship:	Switzerland, Italy

Education

2014 – 2018	PhD student and assistant in the Requirements Engineering Research Group, University of Zurich, Switzerland
2014 – 2017	Research assistant in the ICT for Sustainability Research Group, Empa Materials Science and Technology, Switzerland
2012 – 2014	PhD student and assistant in the ICT for Sustainability Research Group, University of Zurich, Switzerland
2010 – 2012	CAS Renewable Energies and Studies in Environmental Technologies and Management, University of Applied Sciences and Arts Northwestern Switzerland, Switzerland
2001 – 2004	Diploma as Yoga teacher and Yoga therapist
2001 – 2004	Master in Computer Science, University of Zurich, Switzerland 2002: Exchange Semester, University of Lund, Sweden
1998 – 2000	Studies in Computer Science and Physics, Swiss Federal Institute of Technology (ETH), Switzerland
1993 – 1998	High School, Kantonsschule Enge, ZH, Switzerland

Professional Experiences

1996 – 2012	Professional with major achievements in stakeholder-centric software development for technology, health care and car sharing companies.

The place between your comfort zone and your dream
is where life takes place

Helen Keller, Author, 1880 – 1968